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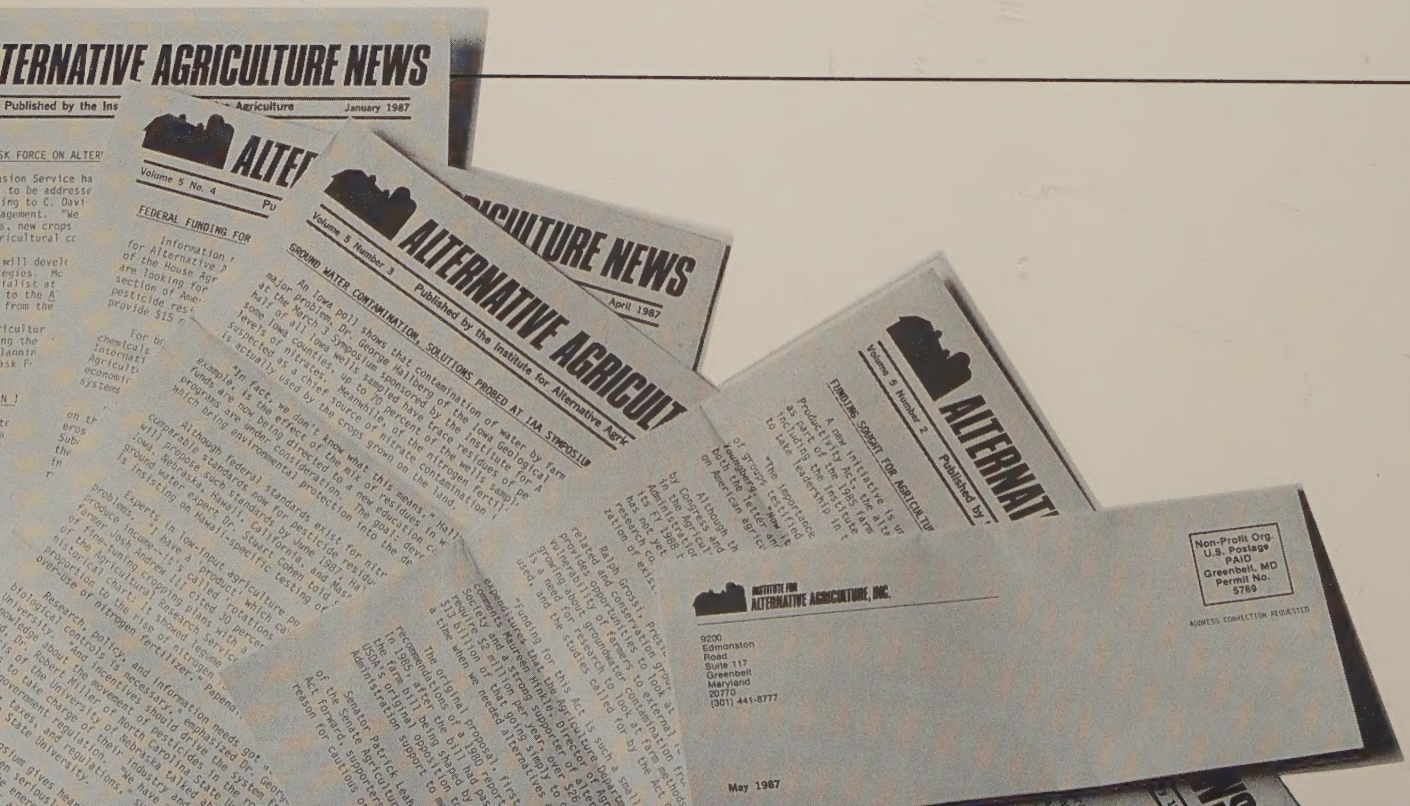

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Wallace Institute Information

The Henry A. Wallace Institute for Alternative Agriculture is a nonprofit, tax-exempt research and education organization established in 1983 to encourage and facilitate the adoption of low-cost, resource-conserving and environmentally-sound farming methods. It works closely with producer groups, public research and education institutions, and government agencies in promoting a sustainable agriculture system.

Its programs include providing a national information clearinghouse, serving as a voice for sustainable agriculture in Washington, and developing and implementing research and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a grass roots Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Cover Photo

The cover photo shows Ms. Jody Ohmacht, a USDA—ARS Research Technician collecting soil samples from the Richard Thompson farm near Boone, IA. An intensive grid sampling was the first step in one of the most comprehensive, inter-agency (USDA and Iowa State University), on-farm evaluations initiated to quantitatively evaluate how alternative (Thompson's) and conventional farming practices are affecting the physical, chemical, and biological characteristics of our nation's soils and the crops they produce. Farming system effects on water infiltration, earthworm number and species, and soil aggregation are discussed in this issue. Profile N concentrations, soil-test characteristics, and spatial variability in crop yields are also being evaluated thanks to the cooperation of the landowners and operators (Mr. and Mrs. Eugene Baker, Mr. and Mrs. Richard Thompson, Mr. and Mrs. David Snyder, and Mr. and Mrs. Steve Snyder).

Photo provided by Dr. D.L. Karlen, Agricultural Research Service, U.S. Department of Agriculture, National Soil Tilth Laboratory, Ames, IA.

A NOTE FROM THE EDITOR

At its annual meeting in March, 1993, the Board of Directors of the Institute for Alternative Agriculture voted to rename the IAA the **Henry A. Wallace Institute for Alternative Agriculture**. It did so to honor the former Secretary of Agriculture's manifold contributions to agriculture and the longstanding support of the Institute by his daughter, Mrs. Jean Wallace Douglas.

To help our readers understand the timeliness and appropriateness of this decision, we asked Professor Don F. Hadwiger, a member of this publication's editorial board and a long-time student of agricultural history, to provide a perspective on the connections between the life and work of Henry A. Wallace and the purposes of the institution which now bears his name. Our thanks to Don Hadwiger for responding so eloquently to our request.

Henry A. Wallace, champion of a durable agriculture

America's farmers, over the years, have received and accepted much good advice about how to value their way of life, how to become more efficient producers, how to maintain prices and incomes, how to preserve the soil and the natural environment, and how to relate to other economic sectors and to farmers in other countries.

One continuing source of enlightened leadership during the past century has been four generations of the Wallace family, beginning with "Grandfather Henry" in the 19th century (Lord, 1947). The family of Wallaces have loved agriculture and respected farmers (they were farmers themselves). They have been thoughtful and farsighted. They have found ways to communicate with farmers, particularly through journals such as *Wallaces' Farmer*. In each era they have worked closely with the other farm leaders. Two of the Wallace's—Henry C., and his son Henry A.—became United States Secretaries of Agriculture.

Secretary Henry A. Wallace in particular created a "new" U.S. Department of Agriculture by adding economic, conservation, and food programs while reinvigorating agricultural research from the "old" department. President Franklin Delano Roosevelt, who named Wallace to the cabinet post, observed that the Department under Wallace became a model for efficient administration, and positioned itself for the emergencies resulting from depression and war, such as the need to provide food assistance to nations besieged by Hitler.

While others advising President Roosevelt focussed on problems of the day, Secretary Wallace was also envisioning ways to address new missions. Wallace, for example, was an exponent of reciprocal trade agreements as a way to increase agricultural markets and promote American prosperity. President Roosevelt, appreciating Wallace's vision, his outstanding record as an administrator, and his loyalty to New Deal principles, chose Wallace as his Vice Presidential nominee in 1940. No other Secretary of Agriculture has been so honored.

Henry A. Wallace envisioned a more enduring world, reborn from depression and war, which would fashion a more humane capitalism. Wallace stated several missions for government, especially in relation to agriculture: to help farmers gain spiritual as well as material rewards from their chosen occupation; to stabilize the agricultural economy; to provide an ever-normal granary that would keep food supplies in readiness for urgent need; to preserve the soil and other natural resources across America and throughout the world; and to increase and sustain food production worldwide in order to meet the needs of a massive human population (Schapsmeier and Schapsmeier, 1968).

Among these goals Wallace was always inclined to give first priority to spiritual and human concerns; but he was convinced that human civilizations lasted only so long as they treasured and protected the fragile natural environments of their agricultures.

Both idealist and realist, Wallace believed that farming provided a unique spiritual experience, and that rural society offered a

wholesome balance within an industrial nation. Wallace anticipated that technological changes would dictate a continuing decline in the number of farmers, but he wanted this decline to be the measure of a vigorous agricultural economy rather than the product of farm distress and unemployment.

The fact that modern agricultural economies were vulnerable to instability concerned Henry A. Wallace, in his first political involvement and throughout his career. In the 1920s Wallace supported the McNary-Haugen bills to provide adequate commodity prices. Later as Secretary of Agriculture, his New Deal programs removed price-depressing surpluses, provided for orderly marketing, and ultimately embodied the mechanism of the ever-normal granary that would store commodities during years of abundance, and during lean years make them available in the market and for food assistance. To Wallace, a stable agricultural economy was a necessary condition for agricultural prosperity, for achieving abundant and moderately priced food, and for building a durable, sustainable agricultural system. In Wallace's mind these goals went together.

Henry A. Wallace always harbored a concern for developing a durable agriculture. He frequently called attention to the importance of maintaining soil fertility. He was particularly concerned about the precarious food situation of the world's populous nations such as India and China. Repeatedly he expressed dismay that more than 100 million acres of farm land in China had been seriously damaged by erosion, and he looked for remedies within Chinese agriculture (such as the practice of returning nutrients to the soil) and remedies also through the application of new technologies. Wallace worried that the United States, with resources plentiful for its modest population, was becoming reckless in the use of them. "Destructive as [the Chinese] may have been," he said, "we in the United States, during the past mere 150 years, have handled our land in a way that indicates even more destructive possibilities" (Wallace, 1934, p. 239).

Far from proposing a simplistic strategy for creating a durable agriculture, Wallace viewed the problem from a full range of perspectives, and found solutions in each perspective. Of course he expected major miracles from new technology: Wallace himself was instrumental in the development of hybrid seeds that multiplied crop yields. From this technology he expected an uninterrupted upward trend in per acre output. With such growing yields, adequate production of crops could be obtained on stable, fertile lands, relieving pressures to crop hillsides and other marginal lands.

Wallace also promoted conservation engineering and cultivation practices developed by soil conservationists. Although the federal soil conservation agency was first established in the U.S. Department of Interior, Wallace subsequently secured its transfer to the USDA under the name of the Soil Conservation Service, and thenceforth Wallace supported the agency's cost-sharing and other innovative programs. Wallace took pride in establishing the goal of soil conservation and rationale for the farm commodity programs, in the Soil Conservation and Domestic Allotment Act of 1936.

Wallace favored certain fundamental practices which have been referred to as organic agriculture and lately as alternative agriculture and sustainable agriculture. For example, Wallace felt it was essential to preserve humus in the soil to insure continued high yields. He said, "...there is more to soil conservation than preserving the chemical element. You must have the humus there too and you must have the manure. It takes organics as well as minerals to blend a truly rich and fertile soil; it takes all kinds of organic material" (Wallace, 1943a, p. 242). Wallace looked for ways to incorporate organic matter into the top layers of soil, finding potential merit in Edward Faulkner's early thesis that the disc was preferable to the plow (Faulkner, 1943). In 1943, Vice President Wallace wrote to farm implement maker Henry Ford, urging him to experiment with alternatives to the plow that might perform even better than the existing disc implements (Wallace, 1943b).

On cultivation as on other aspects of agriculture, Wallace was looking further ahead than most of his contemporaries. His holistic approach kept him open to new perspectives and prepared for inevitable change, ready to shape a more productive and durable agriculture. Henry A. Wallace and other members of his family were preeminent among the agricultural leaders who have offered sound advice to America's farmers.

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Don F. Hadwiger
Iowa State University

OPINION

Family farmers should move toward the animal welfare movement

Denny Caneff

Can one of agriculture's biggest perceived "threats" actually benefit family farmers? Yes, if it is channelled and directed the right way. The animal welfare "threat" may be the salvation of family farming.

Agriculture's Red Scare. Reading the farm press in Wisconsin, one gets the impression that the biggest threat facing family farmers is the animal rights movement. Youth who exhibit animals at fairs get special training in how to handle questions from animal rights activists. An agribusiness representative tells a farm audience that the animal rights movement wants to "make vegetarians out of all of us." A University of Wisconsin dairy scientist tells his students that the animal rights issue ranks third on the list of issues that members of Congress hear about from constituents, after Social Security and the economy. An American Farm Bureau Federation spokesman tells a farm audience that animal rights activists are "penetrating" elementary schools with their messages.

Is the animal rights movement really the unstoppable social juggernaut these observers claim? How many animal rights activists have stormed farms to set the Holstein captives free? Or is this agriculture's Red Scare?

Blown out of proportion....for a reason? Most of these critics of the animal welfare movement ignore an important distinction. The animal rights/liberation/welfare/protection movement is as diverse as any social movement. I list the various descriptors above for a reason: to animal activists, they connote different philosophies about society's use of animals and different tactics for expressing those philosophies.

At one extreme are animal *liberationists*, who believe that humans have no right to control the destiny of any animal. The moderate end of the spectrum, in contrast, is represented by the nation's oldest, best-known, "establishment" animal *protection* organization, the Humane Society of the United States. HSUS resents the blurring of animal welfare ideologies, because such blurring lumps its acceptance of using animals in scientific research and agriculture with the tactics of People for the Ethical Treatment of Animals.

How did animal welfare critics manage to weave this diverse movement into one seamless cut of dangerous cloth? They did it purposely. Many alarms about the animal protection movement (the term that moderates prefer, and the one that I will use) are sounded for farmers. But they are generally sounded by *non*-farmers: representatives of agribusiness companies, organizations of large-scale farmers, and commodity and livestock promotion groups. These groups need farmers as foot soldiers in their war against any social movement that threatens their primacy in the U.S. food system, including the animal protection movement. The farm and commodity organizations rail against the animal protection movement to distract farmer-members from recognizing the real threats facing them, many of which those organizations helped create—like the continuing industrialization of animal production.

Animal protection at the factory farm gate. Factory-style livestock production has little to recommend it for family farmers. As farmer-essayist Gene Logsdon wrote (*Farm Journal*, January 1989), "Which is more of a threat to your independent business as a family livestock farmer: animal rights or animal mega-factories? Think about it." Current trends in livestock agriculture suggest that in the 1990s we will see an accelerated shift of animal production from small, diversified family-operated farms to large-scale, highly mechanized and controlled feedlot and confinement systems.

The industrialization of poultry seems to be paving the way for the industrialization of hog production. Purdue University agricultural economists estimate that 60% of the nation's hog producers will go out of business in the next eight years; those who survive will produce at least 3,000 hogs per year. Hogs, once family farming's "mortgage burner," will become, like their poultry counterparts, production widgets controlled by a handful of food companies.

Animal factories are vulnerable to the criticisms of animal protectionists. The Humane Farming Association has made a national issue of veal crates, for example. There lies the possibility of alliances be-

continued on p. 46

Denny Caneff is Executive Director, Wisconsin Rural Development Center, 1406 Business Hwy. 16/151 E., Mount Horeb, WI 53572.

Effects of intensity of agronomic practices on a soil ecosystem

R.R. Weil, K.A. Lowell, and H.M. Shade

Abstract. *Monitoring soil biological activity may provide useful information in assessing the sustainability of agricultural systems. From 1985 to 1992, we compared five cropping systems in southern Maryland. Four of the systems involved the production of wheat, soybean, or corn, but differed in intensity of tillage, herbicide use, crop biomass removal, and N fertilizer application. The fifth system was continuous grass. The objective was to assess how these cropping systems affected selected indicators of soil biological activity and nutrient cycling. From Fall, 1990 through Fall, 1991 the upper layers (0-5 or 0-15 cm) of soil were studied to assess C and N contents, selected physical properties, extractable organic C, microbial respiration, decomposition of plant tissue, N mineralization, and earthworm* (Lumbricidae) *populations. On a dry weight basis, total and labile C were significantly higher under grass and lower under conventionally tilled (CT) continuous corn than in the other three systems. In fall, there were significantly fewer earthworms (10.4 m^{-2}) under the reduced input rotation than in any other system, and fewer under CT continuous corn than in the organic (corn-wheat-green manure) rotation or grass. In general, the rates of CO_2 evolution were 30 to 35% lower in fall (11.5 to 22.5 kg C ha^{-1} d^{-1}) than in spring (17.3 to 33.7 kg C ha^{-1} d^{-1}). During both seasons, grass had approximately twice as much soil metabolic activity as CT continuous corn. The absence of tillage clearly was important in increasing N mineralization capacity, since the two untilled systems had comparable rates of N release that were significantly greater than those for the other systems. Among the tilled systems, mineral N after laboratory incubation decreased with increasing frequency and intensity of tillage in the order: reduced input > organic > CT continuous corn. It was evident from a combination of measures that soil biological activity was enhanced in the systems that minimized tillage. The results underscored the value of grass for soil improvement.*

Key words: soil organic matter, soil biology, earthworms, soil respiration, cropping systems, N mineralization, organic farming, sustainable agriculture, tillage

Introduction

The activities of soil organisms are largely responsible for the development and maintenance of soil tilth and structure, the synthesis of soil humus and active organic matter, and the cycling of nutrients such as C and N. These biological soil processes often change from their natural state under the influence of agricultural management. Monitoring the status of biological activity and the functioning of the soil ecosystem may provide useful information in assessing the sustainability of agricultural systems.

In their 1977 review of decomposition and respiration in terrestrial ecosystems, Singh and Gupta could cite only six studies on respiration in cropland. Recently, however, the effects of agricultural practices or production systems on soil organisms and their activities have been studied under various conditions. Several researchers have studied the effects of bare fallow and tillage on biological activity in Mollisols of the Great Plains. Follet and Schimel (1989) showed that both mineralization of N and soil respiration were much greater in Colorado prairie soils (Mollisols) kept in native grasses than in similar soils under cultivation. Among the cultivation systems they studied, those with the least tillage maintained the highest rates of these processes. Fallowing, with the soil kept free of weeds by herbicides, caused a great decrease in potentially mineralizable N and C and in actual C turnover in other Great Plains soils (Wood et al., 1990). In a Missouri study, Martyniuk and Wagner (1978) showed that fertilizing crops with animal manure could double soil microbial populations, and that synthetic fertilizers, when used to stimulate the growth of close-growing crops, also increased microbial activity above that in unamended, cultivated soils. The application of organic C as cattle manure (Doran et al. 1987; Fraser et al., 1988) and poultry litter (Weil and Kroontje, 1979) have enhanced microbial and mesofaunal activity in soils compared with treatment with synthetic fertilizers. On the other hand, the type of crop grown often has a greater influence on soil biological activity and carbon than the management practices used in growing that crop (Doran et al., 1987, Angers, 1992).

Because of increased adoption of no-tillage systems, it has become important to investigate the effects that reduced tillage, and its associated increase in herbicide use, may have on the soil ecosystem. With the Conservation Reserve Program putting millions of hectares of land under permanent grass across the U.S., it also is important to know how keeping soil under sod affects biological activity for various types of soils. Most studies so far have used fine to medium textured soils with relatively high soil organic matter, and most have compared cropping systems that involve

Maryland Agricultural Experiment Station contribution No. 8551 and scientific article No. A6367.

R.R. Weil is Professor, and K.A. Lowell and H.M. Shade are Graduate Research Assistants, Agronomy Department, University of Maryland, College Park, MD 20742.

livestock through animal manures and hay crops. Little information is available on indexes of soil biological activity for coarse textured, cultivated soils. In these soils, organic matter levels and buffering capacity are relatively low, and we can expect soil ecosystems to be more sensitive to perturbations.

In 1985, the Accokeek Foundation began a field comparison of several cropping systems proposed as alternatives for farmers in southern Maryland who wished to shift from production of tobacco (*Nicotiana tabacum* L.) to grains without introducing livestock. The five cropping systems studied during the period 1985 to 1992 produced mainly wheat (*Triticum aestivum* L.), soybean (*Glycine max* (L.) Merr.) and corn (*Zea mays* L.), but differed in intensity of tillage, herbicide use, crop biomass removal, and N fertilizer application. The objective of the present study was to assess the effects of these cropping systems on selected indicators of soil biological activity and nutrient cycling.

Materials and Methods

The site

In 1985, a cropping systems comparison was established at Accokeek, Maryland to demonstrate grain production alternatives for southern Maryland farmers. Accokeek has a humid temperate climate, with 1112 mm mean annual precipitation and 19.7°C mean annual temperature. The soil profile was described by auger borings down to 2 m at six locations several meters outside the sampling areas. The textural class of the Ap, E, and BE horizons is sandy loam; Bt and BC are sandy clay loam. The A horizon, the focus of this study, is 10.1% clay and 67.1% sand, and is dark yellow brown (Munsell 10 YR 4/6, moist). The soil is a Woodstown sandy loam (fine loamy, siliceous, mesic Aquic Hapludults), a moderately well drained soil formed from coarse, unconsolidated coastal plain sediments. The site is a western-facing 3% slope adjacent to the Potomac River. The land has been in agricultural use for nearly three centuries and was in lespedeza (*Lespedeza cuneata* (Dumont) G. Don) hay for several years before establishment of the study plots. In November 1984 the entire experimental site was moldboard plowed, disked and seeded to rye (*Secale cereale* L.).

The cropping systems

The original experimental design included four cropping systems (treatments) established in plots 30.5 m by 10.7 m, with the long axis of the plots and the direction of farming operations across the slope. When the plots were laid out in Fall 1984, strips 3.05 m wide between all adjacent treatment plots were planted to tall fescue grass (*Festuca arundinacea* Schreb.). The plots were arranged in a randomized complete block design with four replications. Every second year, including 1991, all four systems produced corn. The four cropping systems in the study are described below.

Cropping system 1 (designated 'no-till') was a two-year, three-crop rotation in which wheat and double cropped soybean alternated with corn, with no winter cover crop between the soybean and corn. System 1 used no-till management and the full rates of herbicides and N fertilizer recommended by the Maryland Cooperative Extension Service for the site conditions. For corn, annual applications of these chemicals per ha included 135 kg N as urea and ammonium nitrate, 1.7 kg metolachlor, 2.8 kg atrazine, and 2.3 kg glyphosate. For soybean, the applications were 3.36 kg glyphosate, 1.7 kg metolachlor, and 1.7 kg linuron. For wheat, selective herbicides were used in some years (2,4-D or Harmony), and N was applied annually at 60 to 100 kg/ha. K and P as potash and triple superphosphate were applied in 1985 and 1987 according to soil test recommendations.

System 2 (designated 'reduced input') differed from system 1 primarily in that herbicides were partially replaced by cultivations, and N fertilizer was partially replaced by a winter cover crop of hairy vetch grown before the corn.

System 3 (designated 'organic') was a rotation that included a clover-grass meadow interseeded into the winter wheat. After wheat harvest, the mixture was grown for green manure to be plowed under before corn planting the following year. In two years, instead of clover/grass meadow, soybean was grown as the green manure in summer, and hairy vetch over the winter. No synthetic fertilizers or pesticides were used in system 3, but rock phosphate and greensand were applied in amounts needed to supply P and K according to soil test recommendations.

System 4 (designated 'continuous corn') was a monocrop of conventionally tilled and fertilized continuous corn, with the same fertilizers and herbicides as in system 1, except for glyphosate.

For this study, one border grass strip was chosen randomly from each replication and designated system 5: 'grass'. No fertilizers or other chemicals were applied to system 5, and the only management after seeding the tall fescue was to mow several times per year with a tractor-drawn rotary mower. The relative intensity of agronomic practices in these five systems is summarized in Table 1.

Soil analysis

In August 1990, a 50 m^2 sampling area was delineated in each plot, including the four grass strips selected as cropping system 5. We took composite soil samples of 12 cores each on October 27, 1990, from 0-5 cm and 5-15 cm, and on October 20, 1991, from 0-15 cm. These samples were air-dried and sieved to pass 2 mm screen before determination of pH (in water) and available P, K, Ca, and Mg extractable in dilute acid by the methods of the University of Maryland Soil Test Laboratory (Bandel and Rivard, 1978). Total C and N were determined by high temperature combustion in a LECO C-H-N Determinator, and organic matter was determined by loss on ignition and Walkley-Black wet oxidation methods. In January 1991, core samples from 0-5 cm were taken from each of the 20 plots to determine bulk density and moisture retention at -12 kPa.

Earthworm populations

Earthworm (*Lumbricidae*) populations were estimated and sampled in Fall 1990 (November 3-25) and in Spring 1991 (March 28 - April 28) by a modification of the dilute formaldehyde expulsion method (Satchell, 1970). We sampled duplicate 0.25 m^2 quadrants from each plot on as level a site as possible, and any vegetation present was clipped off at 1 cm above the soil to improve the visibility of the emerging earthworms. The quadrant borders

Table 1. Relative intensity of agronomic practices in the five cropping systems studied.

Cropping System	Tillage	N Fertilizer	Herbicide use	Biomass removal	Total
1. no-till + chemicals	--[1]	XX	XXX	XXX	8
2. min-till, reduced chem.	XX	X	X	XXX	7
3. reduced till, organic	XXX	--	--	XX	5
4. conv. till, cont. corn	XXXX	XXX	XX	XXX	12
5. grass	--	--	--	--	0

[1] --, X, XX, XXX indicate none, slight, moderate and high intensity of factor.

were delineated by small soil berms 2 to 3 cm high, and two 4.5 l doses of 0.25% formaldehyde were sprinkled on each quadrant and allowed to infiltrate. Simultaneously, we determined soil temperature at 2 and 8 cm with a thermistor probe. All earthworms coming to the surface within 30 minutes were counted, collected, and transported to the laboratory in water. Once in the laboratory, the collections were recounted and subsampled, and the subsample of earthworms blotted gently on paper towels and weighed. Representative specimens were soaked in 70% ethanol and stored in 3.7% formaldehyde solution until identified using the keys of Schwert (1990).

Field soil respiration

During May and again from September 20 to October 10, 1991, we used field respirometers to determine the rates of CO_2 evolved by soil organisms from a given area of soil. In May, the plots were still under the winter cover appropriate for each system, because tillage and planting were delayed until after the respiration measurements were completed. To construct the respirometers, we chose a 25 cm diameter site between clumps of vegetation, and when necessary, clipped off any small plants present at the soil surface. To insure that all sites were at field capacity in the upper layers, the area was then moistened with 0.75 l distilled water sprinkled through a 25 cm diameter 100 mesh sieve. After the water had infiltrated, the sieve was removed and an open 120 ml jar containing 1 *M* NaOH (19.6 cm^2 surface area) was placed on a wire rack that held it approximately 2.5 cm above the soil. A metal cylinder (16.5 cm high and 16.5 cm in diameter), open at one end and painted white on the exterior, was driven 2 cm into the soil to create a sealed chamber for the NaOH container. We placed a plywood 'roof' covered with aluminum foil over the cylinder to prevent heating by direct sunlight.

One such respirometer was set up in each plot. We set up several similar cylinders and instrumented them with thermocouples (wired to a Campbell Scientific Model 21X datalogger), electrical resistance moisture blocks and tensiometers (read every two or three days) to monitor soil temperature and moisture. We also monitored soil temperature and moisture outside these cylinders to check that the cylinders did not greatly alter these factors. To maintain uniform moisture potential near -0.15 bar, the area under each respirometer was remoistened several times as described above. Periodically (see Figure 2), we removed the metal cylinders briefly to allow exchange of the old NaOH container for a fresh one. The removed container was sealed and taken to the laboratory, where enough $BaCl_2$ was added to each container to insure precipitation of all carbonates formed, and the remaining NaOH titrated with 1 *M* HCl to determine how many moles of CO_2 were absorbed. The NaOH from four 'blank' respirometers (sealed on the bottom with a plastic lid and silicone grease) was titrated the same way, to determine a background level of CO_2 absorbed only from the air inside the respirometer. We corrected all CO_2 absorption measurements by the amount absorbed by these blanks. The species and height of vegetation surrounding each respirometer were recorded at the start of the respiration measurements.

Soluble C determinations

At the end of the May 1991 field soil respiration study, we collected soil from 0-5 cm beneath each respirometer in two replications, chilled it immediately on ice, and transported it to the laboratory for immediate extraction by four methods to determine labile organic C. The first method was the boiling water extraction of Davidson et al. (1987). The second and third methods were the 0.5 *M* K_2SO_4 extraction and the 0.5 *M* H_2SO_4 extraction methods of Sikora and McCoy (1990). In the fourth method, 10 g of soil (on an oven-dry weight basis) was shaken with 40 ml of 0.5 *M* $NaHCO_3$ for 1 h and filtered. With all four methods, the C in solution was determined by the modified rapid oxidation method of Nelson and Sommers (1982).

Laboratory soil respiration and residue decomposition

On August 29, 1991, we collected composite soil samples from 0-5 cm from each plot and chilled them on ice for transport to the laboratory, where they were used in an incubation study. Each sample was sieved through a 2 mm sieve in the field moist state and kept at 5°C in plastic containers. We determined moisture content of a subsample of each of the 20 samples by microwave drying (Gee and Dodson, 1981). For each sample, we prepared two incubation chambers. In the first we placed 110 g field moist soil, in the second a mixture of 110 g field moist soil plus 1.0 g dried, ground alfalfa (*Medicago sativa* L.; analysis 3.38% N, 42.6% C, 0.315% S). Treatment with alfalfa was included to allow us to determine the ability of the soils to cycle C and N from added crop residues. Using

previously determined moisture contents for the soils and alfalfa at -0.1 bar potential, enough distilled water was added to each flask to bring all soils to -0.1 bar potential. Four 'blank' chambers also were prepared without any soil to allow correction for CO_2 absorbed from the air alone. Each incubation chamber was made from a 250 ml Erlenmeyer flask with an inflow and outflow tube. The incubation chambers were randomized on the laboratory bench and wrapped in aluminum foil to exclude light. During the 1023 h incubation, air was continuously pulled through a train consisting of: 1) a test tube with 40 ml of 2 *M* NaOH to remove atmospheric CO_2; 2) a tube with 35 ml of distilled water to saturate the air with moisture; 3) the incubation chamber containing the moist soil (with or without amendment); 4) a safety trap to prevent back flow; and 5) a test tube with 25 ml of 1 *M* NaOH to trap the CO_2 given off by the soil organisms. Periodically, we replaced this last tube with a fresh tube of NaOH, and determined the CO_2 absorbed by titration after adding $BaCl_2$. The soil was incubated in the dark at room temperature (22 to 26°C). Soil moisture was monitored by periodic weighing; it was 14.9 g/kg at the start and 14.7±0.2 g/kg at the end of the incubation.

Nitrogen mineralization

When the soil samples were being apportioned to the incubation chambers described above, 10 g of each was dried at 60°C for 9 h. Later these subsamples were shaken in 24 ml of 0.1 *M* K_2SO_4 for 15 minutes and filtered. The filtrate was analyzed for nitrate-N by the salicylic acid method modified from Cataldo et al. (1975), and for ammonium-N, after raising the pH to convert all NH_4^+ to NH_3, using an Orion ammonium selective electrode and Orion millivolt meter, Model 940. We repeated these analyses on 10 g subsamples from both the amended and unamended soils from the incubation chambers after the end of the incubation.

Statistical analysis

All statistical analyses were performed using the SYSTAT 5.0 computer package. For the earthworm data, homogeneity of residual variances was obtained by a square root transformation. We performed analysis of variance for most variables using the randomized complete block design of the field experiment. Means were separated using an F protected Least Significant Difference or by orthogonal single degree of freedom contrast statements. The significance level chosen was 0.05, unless otherwise stated. Correlations between variables were calculated by the Pearson correlation matrix.

Results

Soil chemical and physical properties

With the following exceptions, six years of management under different cropping systems had little effect on most physical and chemical soil properties (Table 2). The most marked change was that available P was nearly twice as great in the cropped systems compared to grass, because the former were fertilized with P while the latter was not. Grass was the only system where P was near the 'low' range as defined by the University of Maryland Soil Test Laboratory, and, therefore, the productivity and biological activity in that system may have been limited by availability of P. A second notable difference in the soil test values is the slightly lower pH in no-till and continuous corn, probably a result of the acidifying effect of the higher rate of N applied to these plots as urea. Only continuous grass was significantly higher than other systems in soil organic matter (as determined by loss on ignition), total C, and total N. This agrees with the results of other studies that have found tillage to be the prime determining factor in C accumulation or loss (e.g., Wood et al., 1990; Weil et al., 1988). Other measures of organic matter accumulation and quality will be discussed later.

Bulk density is an important soil physical property that is directly related to total pore space available for air and water storage and root growth. There was a close negative relationship between bulk density at 0-5 cm and soil C at 0-15 cm, with soils under grass having a significantly lower bulk density than in the other systems. In addition, when water was added to the soil during the earthworm collections and in preparation for the field soil respiration measurement, infiltration rate was negatively related to intensity of tillage. In the

Table 2. Carbon and N (0-15 cm) in Fall 1990, bulk density (0-5 cm) in January 1991, and pH, organic matter, dilute acid extractable Mg, P_2O_5, K_2O, and Ca (0-15 cm) in Fall, 1991.

Cropping System	pH	Mg	P_2O_5	K_2O	Ca	Organic Matter	Total C	Total N	Bulk Density
		mg/kg				%			(g/cm^3)
1. no-till + chemicals	5.9b[1]	103ab	56a	82a	467ab	1.95a	0.75b	0.07b	1.34a
2. min-till, reduced chem.	6.1a	115a	55a	76a	428b	1.83a	0.70b	0.07b	1.35a
3. reduced till, organic	6.1a	113a	58a	53a	536a	1.73a	0.85b	0.09ab	1.29a
4. conv. till, cont. corn	5.9b	94c	60a	71a	420b	1.68a	0.70b	0.08b	1.38a
5. grass	6.0ab	120a	34b	77a	515a	2.28b	1.11a	0.10a	1.15b
MEAN	6.0	109	52	72	474	1.97	0.82	0.08	1.30

[1] Values in a column followed by the same letter do not differ at the 0.05 level of significance.

continuous plowed corn, water took about ten times as long to infiltrate as in grass; the other systems were intermediate in infiltration rate. The water holding capacity (water content at -12 kPa) averaged 149 g/kg, and did not differ significantly among cropping systems.

The organic C in soils occurs mostly in very stable humic compounds that have half-lives for microbial decomposition ranging from decades to centuries (Anderson and Coleman, 1985). Although this stable humus fraction has important effects on soil buffering capacity and moisture retention, most biological activity is governed by the supply of easily metabolized, so-called 'available C' (Sikora and McCoy, 1990). Standard methods for determining soil organic C include all or most of the total C present, but several methods have been proposed to selectively extract the portion that is readily available to soil microorganisms. The results of four such extraction methods are presented in Table 3. All four methods extracted only a few percent of the total organic C, but the $NaHCO_3$ extraction best reflected the results of the soil respiration and mineralization studies discussed below. $NaHCO_3$-extractable C was significantly higher under grass and lower under continuous corn than in the other systems. As a fraction of total C, it ranged from 4.7% under the reduced tillage, low chemical system to 2.2% under continuous corn (data not shown). Hot water extractable C did not distinguish between grass and continuous corn, while the other two extractants did not distinguish between continuous corn (the most tilled) and no-till (the least tilled of the cropped systems). Although the $NaHCO_3$ results are encouraging, further work is needed to develop a simple soil test procedure that can provide information on the quality of soil organic matter as it pertains to soil tilth and biological activity.

Earthworm populations

Although there can be little doubt that the largest share of organic matter assimilation and C turnover is accomplished by microorganisms, earthworms can greatly enhance microbial activity. They also have a major influence on soil structure, soil fertility, aeration, and drainage (Edwards, 1980). Therefore, they are a key component of the soil ecosystem, both as indicators of biological activity and C turnover and as creators of improved fertility and tilth (Daugbjerg et al., 1988). Their numbers and biomass are thought to be sensitive to such agricultural practices as pesticide use, crop rotation, fertilizer use, crop residue management, and especially tillage.

Unfortunately, complete enumeration of earthworm populations is not possible by any of the several methods available (Satchell, 1970). In addition, both the actual numbers of earthworms and their susceptibility to collection by various methods fluctuate with seasons and soil conditions. The dilute formalin expulsion method used in this study is expected to enumerate most vertical burrowing earthworms that are active in the Ap horizon during sampling. The method also is affected by soil moisture and temperature, an optimum temperature of 10.6°C having been suggested by Satchell (1970). Best results are expected in the spring and fall, when the surface soil moisture is plentiful and temperature is moderate.

We did not attempt detailed classification, but the predominant species in both the fall and spring collections were: *Aporrectodea trapezoides*, *Allobophora chlorotica*, *Lumbricus rubellus*, and *L. terrestris*. Figure 1 shows the total numbers and biomass of the earthworms collected in Fall 1990 and Spring 1991. In the fall there were significantly fewer earthworms ($10.4\ m^{-2}$) in the reduced input system than in any other system, and fewer in continuous corn than in the organic or grass systems. Tillage during establishment of the hairy vetch cover crop in the reduced input system about a month before the fall earthworm collection was probably responsible for its very low earthworm density and biomass. The relatively low earthworm density in continuous corn is probably related to the intensive tillage used every spring and early summer, and to the lower soil organic matter content in that system. In spring, although their density had increased to $56\ m^{-2}$, fewer worms with lower total biomass were again collected from the reduced input system. With no tillage between July and the time of earthworm collection in April, continuous corn showed the most dramatic fall to spring increase in earthworm density and biomass.

Table 3. Total organic carbon by wet digestion and carbon in four extracts of the upper 15 cm of soil collected at the end of the spring field respiration study (g/kg).

Cropping System	Total Organic C	Extractable Available C			
		Hot Water	5 *M* K_2SO_4	0.1 *M* H_2SO_4	$NaHCO_3$
1. no till + chemicals	11.0	0.31	0.55	0.44	0.32
2. min. till, reduced chem	8.3	0.27	0.40	0.26	0.29
3. reduced till, organic	9.6	0.21	0.43	0.29	0.23
4. conv. till, cont. corn	7.9	0.31	0.46	0.32	0.12
5. grass	20.0	0.37	0.67	0.64	0.51
$LSD_{0.05}$	4.8	0.10	0.21	0.18	0.15

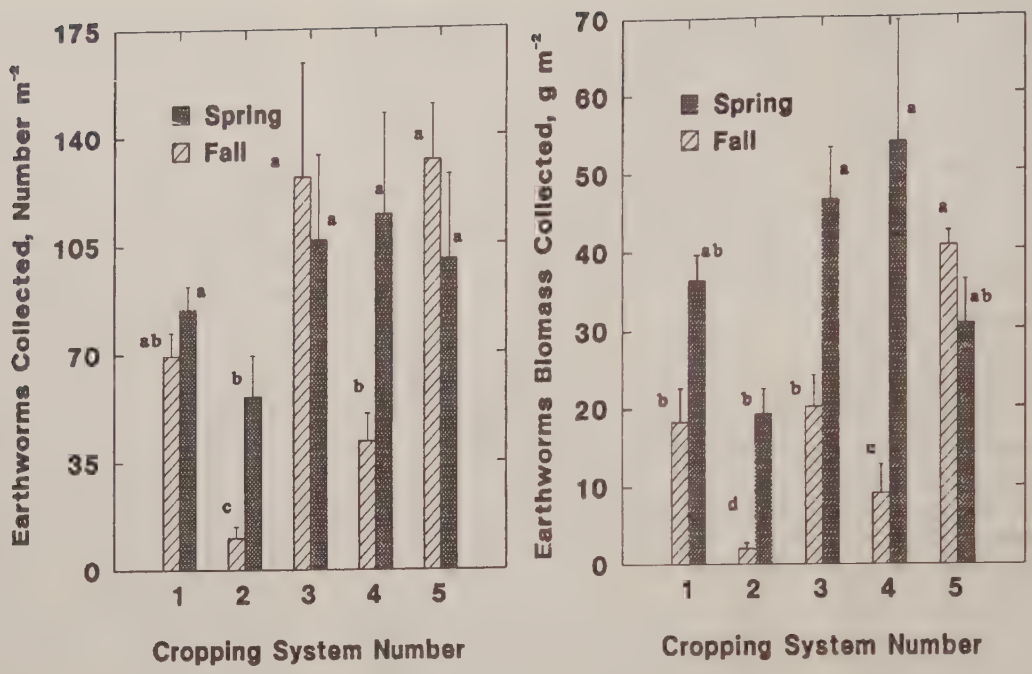

Figure 1. Density (left) and total biomass (right) of earthworms collected in Fall 1990 and Spring 1991 from the cropping systems plots at Accokeek, Maryland. For a given season, bars marked with the same letter do not differ significantly at the 0.05 level. Data were square root transformed prior to analysis of variance. Error bars represent one standard deviation with blocking effect not removed.

It is difficult to explain why the spring earthworm biomass was greatest in continuous corn, but the result may have been an artifact of the long time (up to 15 min) that the formaldehyde solution remained ponded on the soil surface in these plots. An alternative explanation is that these plots had more bare soil exposed and therefore warmed earlier in spring, causing earthworms to be more active nearer the surface than in the other plots. However, soil temperature at 8 cm measured at the time of earthworm collection was higher in these plots than the other cropped plots (22 versus 19 to 20°C) only once. On the other hand, the earthworm densities reported for the grass plots in spring may be underestimates because soil temperature was consistently 1 to 2°C lower in those plots than in the others (data not shown). The range of earthworm density and biomass found in this study were very similar to those reported by Werner and Dindal (1990), who used a similar expulsion method at corresponding periods in the cropping cycle in finer textured soils with higher organic matter content at the Rodale Research Institute in Pennsylvania. Although cropping system did not affect worm weight in the present study, there was a seasonal variation. On average, worms were larger in the spring (0.436 g per worm) than in fall (0.244 g per worm). There was a significant variation of earthworm size among experimental blocks: fewer but larger earthworms were collected from plots farther up the slope away from the river.

Field soil respiration measurement

The rate of CO_2 evolution from a soil, sometimes called soil respiration, is a direct and sensitive measure of the total metabolic activity of all organisms in that soil. In the field, plant roots contribute to the evolution of CO_2 from soils. Macfadyen (1970) suggested that in forested soils, roots may account for as much as half the soil respiration, but directly contribute considerably less under grass and herbaceous vegetation. Roots can contribute to soil respiration directly by their metabolic activity and indirectly by providing organic compounds that serve as metabolic substrates for soil organisms. The activity of the soil community is governed by the amount and availability of organic C, by the supply of available N and other nutrients, by attributes of the microbial and faunal populations, and by soil moisture and temperature. Since we were interested in the effect of cropping systems on soil organisms and nutrient availability, we attempted to maintain uniform soil temperature and moisture by insulating and shading the respirometers and by adding water to keep the soil within a narrow range of moisture content.

That this effort was successful is shown by the nearly constant rate of CO_2 evolution for a given cropping system during the nearly 500 h measurement period in both spring and fall of 1991 (Figure 2). The variance is comparable to that of laboratory incubation studies in which environmental variables are closely controlled. Soil disturbance and root pruning from the initial installation of the respirometers apparently had minimal effects, because there was no pronounced initial flush of CO_2. Also, differences in soil respiration measured among systems were little affected by the vegetation surrounding the

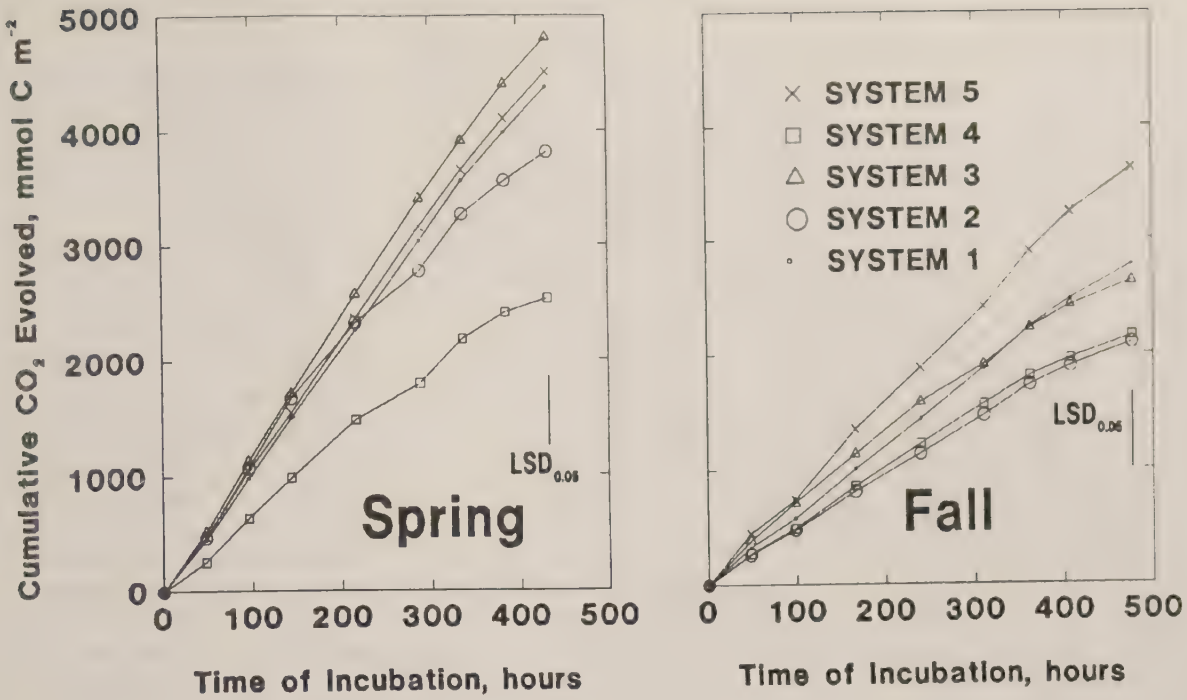

Figure 2. Cumulative CO_2 evolved in the field from soil under five cropping systems at Accokeek, Maryland before Spring 1991 tillage and planting (left), and after corn had matured in fall (right). The LSD bar applies to the means of CO_2 accumulated by the final measurement.

respirometers, either through root respiration or otherwise. Thus, no-till and continuous plowed corn, which had vegetation in spring consisting of similar populations of annual weeds, had very different soil respiration rates (10.1 versus 5.8 mmol C m^{-2} h^{-1}), but for the reduced input system, which had a lush 60 cm tall stand of hairy vetch, the rate was moderate (8.8 mmol C m^{-2} h^{-1}).

In spring, the cumulative CO_2 evolved was highest for the no-till, grass and organic systems, which had the lowest intensity of tillage and biomass removal (Table 1). It was lowest for continuous corn, which had the highest tillage and biomass removal, and intermediate for the reduced input system. In fall, CO_2 evolved again was high for grass and low for continuous corn, but the no-till and organic systems were intermediate. In general, the rates of C turnover were 30 to 35% lower in fall (11.5 to 22.5 kg C ha^{-1} d^{-1}) than in spring (17.3 to 33.7 kg C ha^{-1} d^{-1}). During both seasons, the grass plots had approximately twice as much metabolic activity as the continuous corn.

Laboratory soil respiration

Sieved soil samples obtained shortly before the fall field respiration measurements and incubated in the laboratory with or without ground alfalfa tissue (0.9% by weight) evolved CO_2 at rates that tended to confirm that the field respiration measurements reflected the attributes of the soil microbial population, and not merely differences in root respiration or the supply of crop residues. Thus, for both the amended and unamended soils, the grass system produced the most CO_2, and continuous corn the least (Figure 3).

Adding alfalfa tissue to the soil incubated in the laboratory accelerated the rates of respiration initially by a factor of 20 to 25, but after 800 h the slopes of the curves were greater than those of the unamended soil by a factor of only 2 to 3. The random variability of CO_2 evolution within a system was considerably less for the amended soil, possibly because a uniform addition of readily decomposable organic matter overshadowed any sampling variations in the field soil organic matter content. The respiration rates in the unamended soils reflect both the amount of organic substrate present as result of the cropping systems, and the size and activity of the microbial populations. The respiration rates in the amended soils primarily reflected the ability of soil organisms in each system to turn over C in crop residues where N was not limiting.

Mineralization of nitrogen

Mineral N was measured in the soil samples before and after the incubation discussed above. The analysis of variance on the N data is reported in Table 4. The cropping system and the alfalfa tissue amendment both had pronounced effects on soil N, but there were no significant interactions between these two factors. Table 4 provides statistical information for the data presented in Figure 4. Figure 4a shows the concentrations of mineral N (both nitrate and ammonium) present in the upper 15 cm of the soils when the corn was mature and N uptake had ceased. The levels of residual nitrate-N were quite low, equivalent to approximately 10 kg N/ha to a depth of 15 cm, and did not differ among cropping systems. Ammonium-N, on the other hand, was unusually high (approx-

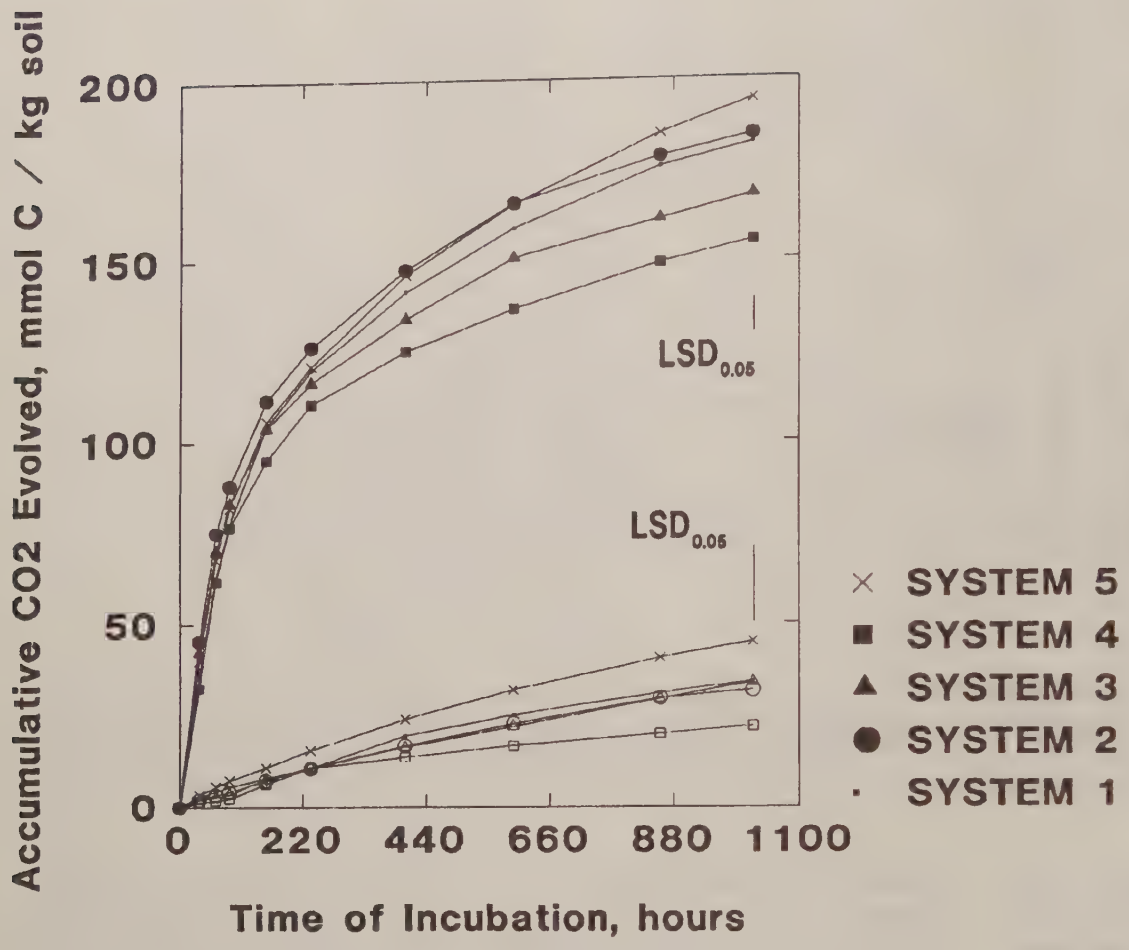

Figure 3. Cumulative CO_2 evolved during a laboratory incubation at 20 to 25°C and 0.1 bar soil moisture potential. Filled symbols are for soil amended with 1 g dry alfalfa per 110 g soil. Open symbols represent unamended soils. LSD bar applies to the means of CO_2 accumulated by the final measurement.

Table 4. Analysis of variance results for nitrogen data from laboratory incubation of soils with or without alfalfa amendment. Values are significance levels.

Effect	Pre-Incubation			Post-Incubation			
	NO_3^--N	NH_4^+-N	Mineral N	NO_3^--N	NH_4^+-N	Mineral N	N Release
Rep	>.1	<.01	<.01	<.01	<.01	<.01	<.01
Treatment	>.1	<.01	<.01	<.01	<.01	<.01	<.01
Trt x Amendment	na	na	na	>.1	>.1	>.1	>.1
System 1 v 5	>.1	<.01	<.01	<.05	<.01	<.01	>.1
System 4 v 5	>.1	<.01	<.01	<.01	<.01	<.01	<.01
System 1 v 4	>.1	<.1	>.1	<.01	>.1	<.01	<.01
System 1-4 v 5	>.1	<.01	<.01	<.01	<.01	<.01	<.01
System 2 v 3	>.1	>.1	>.1	<.05	>.1	<.01	<.01
System 1 v 2	>.1	>.1	>.1	<.05	>.1	<.1	<.05

imately 12 to 30 kg N/ha to 15 cm) and was significantly higher in the grass plots than in the other systems.

It is unusual for ammonium to account for so much of the mineral N present in soils late in the season. The high levels of ammonium-N probably resulted from a flush of mineralization that may have occurred when rain that fell a few days before the samples were collected rewet the soils after a very hot and dry summer. Apparently, nitrification lagged behind mineralization at this time.

After 1023 h of incubation, the ammonium-N concentrations had decreased slightly (Figure 4b), but soil from the grass system had the highest concentrations. By contrast, nitrate-N increased nearly tenfold during the incubation, with significantly more being produced for the grass system than for the other systems. Also, the organic and continuous corn systems had significantly less nitrate-N than no-till and reduced input systems. The low level of soil nitrate in the organic system may reflect the lower N inputs into that system, while in continuous corn it may partially have been due to greater N uptake by corn, since weed competition for moisture had greatly reduced corn production in the other systems in 1991.

Total mineral N (nitrate plus ammonium) after incubation followed a pattern similar to that of nitrate-N alone (Figure 4b). The differences in mineral N released from the five soils during incubation do not appear related to total N or C:N ratio (see Table 2). Rather, they reflect the nature of the soil organic matter in these soils and the ability of the respective soil microbial communities to mineralize N.

As expected, the addition of alfalfa tissue to the soil greatly increased the mineral N, principally in the nitrate form, by the end of the incubation (Figure 4c). The no-till soil was higher in mineral N than that of the other cropped systems, but was lower than the soil from under grass. The differences in mineral N in the soils before and after incubation with alfalfa reflects the ability of organisms in these soils to release N from crop residues. The lack of tillage clearly favored high N mineraliza-

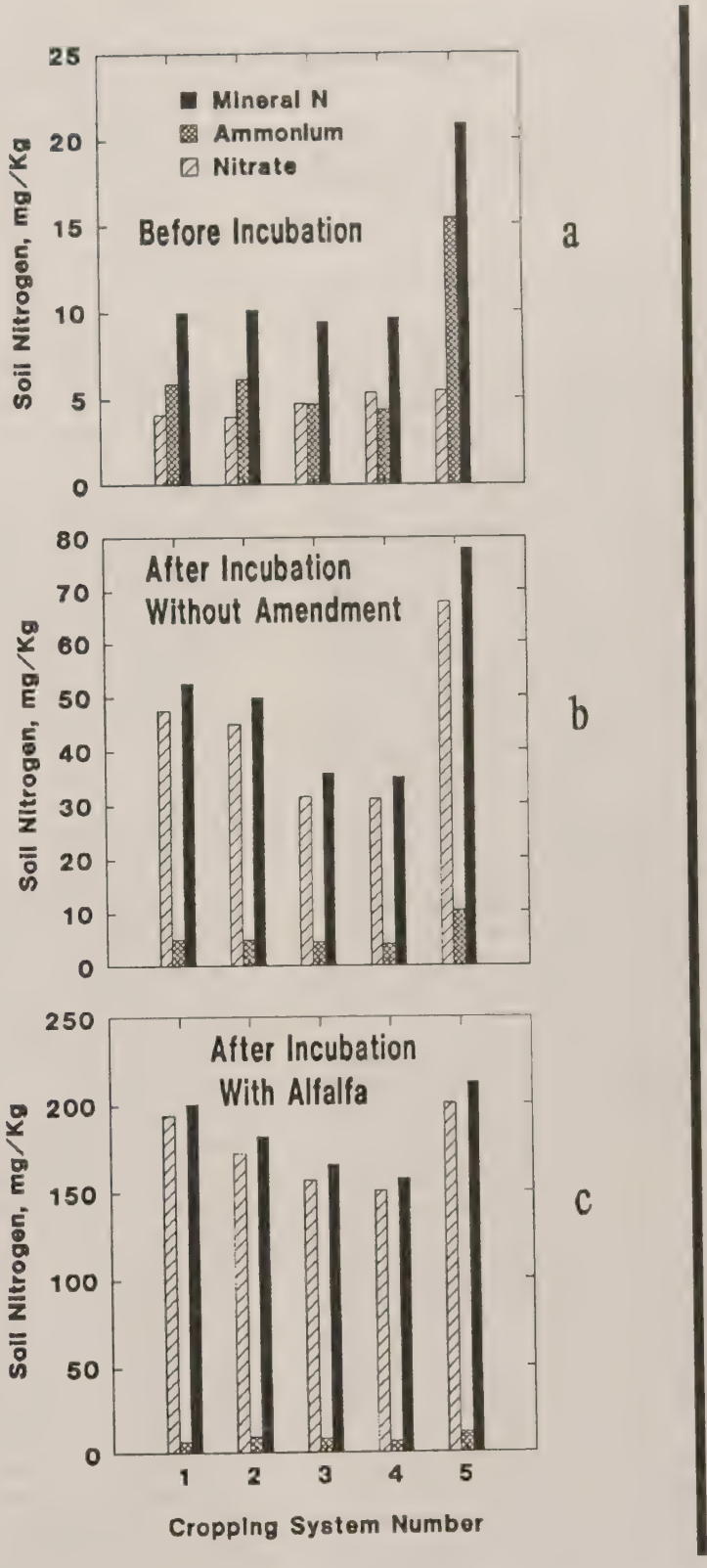

Figure 4. Ammonium-N, nitrate-N and total mineral N extracted from fresh soil sampled from five cropping systems. Results are shown for soils prior to incubation (a), after 1023 hours of incubation without amendment (b), and after 1023 hours of incubation with 1 g alfalfa per 110 g soil (c). Refer to Table 4 for statistical interpretations.

tion ability, since the two untilled systems (no-till and grass) had comparable rates of N release that were significantly greater than those of the other systems. Among these systems, mineral N after incubation decreased with greater frequency and intensity of tillage, in the order: no-till > reduced input > organic.

Summary and Conclusions

The combination of several measures (organic matter accumulated, soil porosity, field soil respiration, CO_2 evolved during incubation, and mineral N released) shows clearly that soil biological activity was enhanced in the systems that minimized tillage. Surprisingly, the abundance of earthworms, which are considered very sensitive to damage by tillage, did not always follow the same pattern. We do not know the reason for the response of earthworms, but in part it may have been an artifact of the interaction of the collection technique with soil properties such as infiltration rate and temperature. The most dramatic improvement in porosity, organic matter accumulation and N mineralization ability came from five years' continuous growth of grass sod, underscoring the potential role of grass in sustainable cropping systems and the value of grass for soil conservation and improvement.

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Nation's Largest Study of Cancer and Farmers is Launched

An Agricultural Health Study, the nation's largest epidemiologic study of farmers and their families, has been announced by the EPA, the National Cancer Institute, and the National Institute of Environmental Health Sciences. The 10-year study will identify and assess factors that may account for previously reported high cancer rates among farmers; $15 million will be spent to study 75,000 farmers, their families, and pesticide applicators. For further information, contact the Cancer Information Service at 1-800-4-CANCER.

Comparison of alternative farming systems. I. Infiltration techniques

S.D. Logsdon, J.K. Radke, and D.L. Karlen

Abstract. *Quantitative data are needed to understand how alternative farming practices affect surface infiltration of water and associated surface soil properties. We used a rainfall simulator, double ring infiltrometer, small single ring infiltrometers, and tension infiltrometers to measure water infiltration for Clarion loam (fine-loamy, mixed, mesic Typic Hapludoll) and for Webster silty clay loam (fine-loamy, mixed, mesic Typic Haplaquoll) soils located on a conventionally-managed and an alternatively-managed farm in central Iowa. Steady-state measurements suggested that infiltration rates were somewhat higher for the alternative farming system. Bulk densities were sometimes lower, and volume of large pores was a little higher for the alternative farming system. Small single rings were more reproducible than rainfall simulators or double ring infiltrometers, and data trends were the same as for rainfall simulators.*

Key words: macropores, alternative agriculture

Introduction

Quantitative evaluations of the long-term effects of alternative farming practices on soils are required to enable us to distinguish between the real and supposed environmental impacts of alternative farming systems. For example, the National Research Council's *Alternative Agriculture* report (1989) has been criticized for a lack of quantitative data comparing alternative and conventional farming systems (Council for Agricultural Science and Technology, 1990).

Comparing farming systems requires a substantial equilibration period and adjacent farms that are managed differently with known management records. An adjacent location is required to equalize soil-forming factors, including parent material, natural vegetation, microclimate, and microtopography (Reganold, 1988). Farming system comparisons between adjacent alternative and conventional farms are often criticized for a lack of replication. Soil map units, which provide valid interpretations for land use (Hudson, 1990) and crop yield (Karlen et al., 1990), provide a semi-replicated approach for comparing farming systems and designing agrochemical residue sampling programs (Karlen and Fenton, 1991).

Infiltration measurements provide an indirect, integrated assessment of a farming system's influence on hydrologically effective macroporosity, surface seals, and soil density. Different types of infiltration measurements include rainfall simulator, double ring infiltrometer, small single ring infiltrometer, and tension infiltrometer. Our purpose was to study the effectiveness of different types of infiltration measurements in investigating the effects of alternative farming systems on water flow properties.

Methods

This farming system evaluation was conducted on four adjacent 16 ha (40 acre) fields (Fig. 1) on the Des Moines lobe in central Iowa. Long-term soil and crop management records (Table 1) were obtained from cooperators to verify that farming practices were consistent for a sufficiently long period.

We recognize that in this approach, each farming system is practiced on the particular distribution of soils that happens to be found on the respective field; however, we needed to work on farmers' fields to get the long-term management histories and to do the study on a field scale. On farmers' fields, it is not possible to assign the treatments randomly; therefore, specific treatment effects cannot unambiguously be separated from field effects using customary experimental designs and statistical analysis methods. By using map units to identify similar soils within each field, we can establish a semi-replicated design for comparing farming systems (Karlen and Fenton, 1991). The underlying assumption for this approach is that soil map units, even though they may contain inclusions of similar soils, are very much alike because they occur on similar topographical and landscape positions. At this site, for example, Clarion soils are always found on the hilltops and upper sideslopes, whereas Canisteo (fine-loamy, mixed [calcareous], mesic Typic Haplaquoll) and Webster occur in the toeslope positions.

The relation between the last two soils requires clarification. The soils are very similar, differing only in that Canisteo has free calcium carbonate at the surface. Webster occurs as an inclusion within Canisteo map units. A finer-grained survey of this site done concurrently with this study by a soil morphologist (Steinwand, 1992) revealed that the map unit called "Canisteo" is primarily Webster. In 1991, therefore, to control further for soil type, the samples shown as from Map Unit 507 (Figure 1) were taken exclusively from Webster soils. To avoid inconsistency with

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S.D. Logsdon, J.K. Radke, and D.L. Karlen are Soil Scientists, USDA-ARS, National Soil Tilth Laboratory, 2150 Pammel Dr., Ames, IA 50011.

the published soil survey, we refer to the 1989 data as from Canisteo soils.

1989 studies

Preliminary studies in 1989 were on adjacent 32 ha fields on the Clarion-Nicollet-Webster soil association in Boone County, Iowa. The alternative system (east half of the study area) is part of the Richard and Sharon Thompson farm and was Case Study No. 5 in the *Alternative Agriculture* report (National Research Council, 1989, pp. 308-323). This field represents alternative farming practices based on a 5 year rotation of corn (*Zea mays* L.), soybean (*Glycine max* [L.] Merr.), corn, oat (*Avena sativa* L.) and mixed hay. The hay consists of a mixture of alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.), alsike clover (*Trifolium hybridum* L.), timothy (*Phleum pratense* L.), and orchard grass (*Dactylis glomerata* L.). Weeds are controlled without herbicides. Manure and municipal sludge supply the plant nutrients, and row crops are ridge-tilled.

The conventional system (west half) is owned and was farmed by Eugene and Dorothy Baker from 1932 to 1980. It has been farmed by David and Steve Snyder as part of a 700 ha custom operation since 1981. Corn and soybean have been grown in rotation using conventional practices since 1957. In 1989, corn was grown on the south 16 ha of both fields. Long-term soil and crop management practices for both farming systems are summarized in Table 1.

Mr. Snyder applied 134 kg N/ha as anhydrous ammonia to the conventional field in November 1988. A field cultivator was used to prepare a seedbed and incorporate broadcast N-P-K fertilizer (35-38-93 kg/ha), and 5.8 l/ha Eradicane (S-ethyl-N,N, dipropylthiocarbamate plus N,N-diallyl-1,1-dichloroacetamide). On 2 May 1989, Pioneer Brand 3615 hybrid corn was planted using a 12-row John Deere planter. The crop was cultivated on 10 June 1989.

On 8 May 1989, Mr. Thompson planted the alternative field with Pioneer Brand 3379 hybrid corn, using 4-row Buffalo ridge-tillage equipment. Manure and municipal sludge had been applied to this field at 45 Mg/ha the previous day. Estimated N-P-K content of this material was 6.6-1.8-4.1 kg/Mg (Rodale Institute, 1990). This rate of application provided 295-82-186 kg/ha of N-P-K. Weeds were controlled without herbicides by rotary hoeing the crop on 15 and 23 May and cultivating on 1 and 20 June. During the final cultivation, ridges were rebuilt as part of the ridge-tillage practice. Rainfall was 116 mm in May, 92 mm in June, and 9 mm in July before the infiltration measurements.

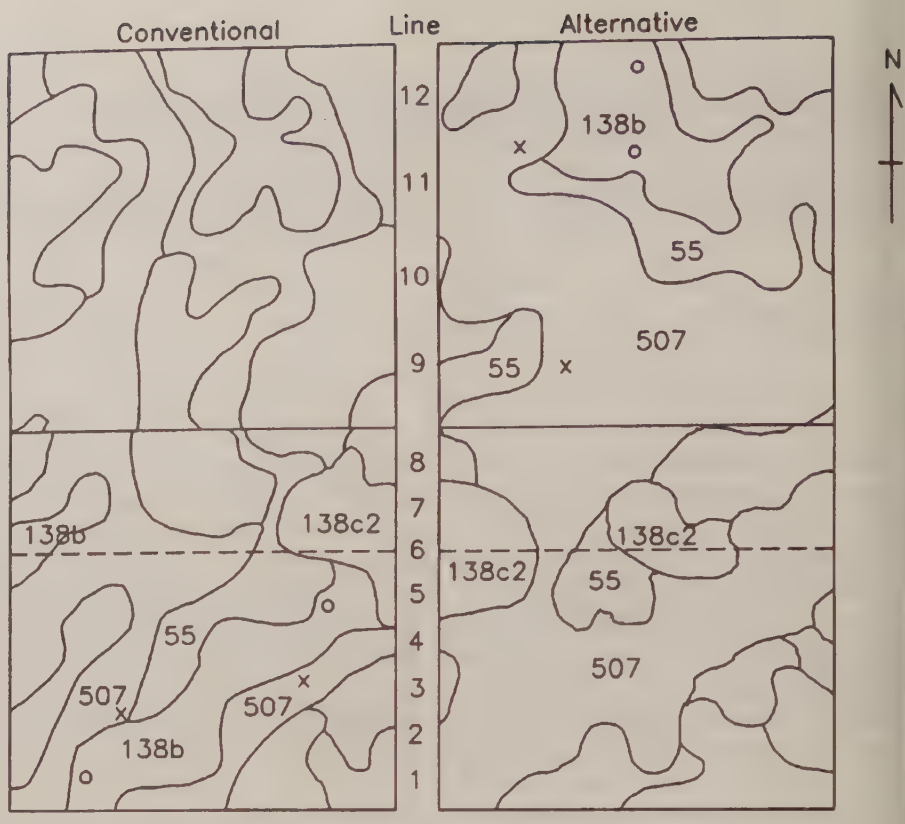

Figure 1. Site map and description of soils at the research site.

Figure legend:

Dashed line indicates transect for measurements in 1989.
Symbols indicate sites for 1991 measurements.
Soil identification:

Soil Type	Map Unit	Classification
Clarion loam		Fine-loamy, mixed, mesic Typic Hapludolls
2 to 5%slopes	138B	
5 to 9% slopes	138C2	(moderately eroded)
Nicollet loam	55	Fine-loamy, mixed, mesic, Aquic Hapludolls
Canisteo silty clay loam	507	Fine-loamy, mixed (calcareous), mesic, Typic Haplaquolls
Webster silty clay loam	107	Fine-loamy, mixed, mesic Typic Haplaquolls

We measured infiltration in both southern fields for two sampling sites along transect 6 (Fig. 1) on Clarion loam (138C2) and Canisteo silty clay loam (507) soils. After removing the corn crop at anthesis (11 to 14 July), we used an oscillating rainfall simulator (Kay and Baker, 1989), providing water at an intensity of 64±14 mm/hr. The rainfall simulator, which was built by

Table 1. Farmer-supplied information on management practices used for the two farming systems on the Clarion-Nicollet-Webster soil association in central Iowa.

		Conventional System
Rotation	1932-1957	Corn, oat and hay
	1957-1991	Corn and soybean
Fertility	1932-1979	Hog manure and 0-17-33 kg N-P-K/ha applied to corn
	1960-1980	As above, plus 112 kg N/ha
	1981-1991	168-38-93 kg/ha of N-P-K applied to corn
Tillage	1932-1981	Moldboard plow, disking, and harrowing
	1981-1991	Chisel plow and field cultivator
Pesticides[1]	Before 1981	"Low" rates of atrazine plus occasional applications of 2,4-D during the early 1960s
	1981-1991	Combinations of banvel, butylate, 2,4-D, cyanazine, alachlor, EPTC + R25788, and atrazine for corn Combinations of basagran, trifluralin, and alachlor for soybean
	1988	Dimethoate on soybean for spider mite control
		Alternative System
Rotation	1967-1991	5 years: corn, soybean, corn, oat, and hay
Fertility	1967-1984	No commercial fertilizer; cattle and hog manure applications, total of 45 Mg/ha yearly on row crops, none on oat or hay crops.
	1984-1987	Municipal sludge mixed with manure
	1988-1991	Manure/sludge plus 112 kg/ha K as kiln dust in the manure/sludge mixture
Tillage	1967-1980	Moldboard plow, disking, and harrowing
	1980-1991	Ridge-tillage, disking before oats
Weed control	1967-1991	Rotary hoe and cultivate; no herbicides
Cover crops	1984-1991	Hairy vetch (*Vicia villosa* L.), oat, and winter rye (*Secale cereale* L.)

[1] Atrazine: 2,chloro-4-ethylamino-6-isopropylamino-1,3,5 triazine; 2,4-D: 2,4-(dichlorophenoxy) acetic acid; Banvel: dimethylamine salt of 2-methoxy-3,6-dichlorobenzoic acid; Butylate: S-ethyl diisobutylthiocarbamate; Cyanazine: 2-{[4-chloro-6-(ethylamino)-S-triazin-2-yl]amino}-2-methylpropionitrile; EPTC + R25788: S-ethyl-N,N, dipropylthiocarbamate plus N, N-diallyl-1,1-dichloroacetamide; Alachlor: 2-chloro-2′-6′-diethyl-N-(methoxymethyl)-acetanilide; Basagran: 3-(1-methylethyl)-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide; Trifluralin: α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-ρ-toluidine; Dimethoate: O,O dimethyl S-(N methylcarbamoylmethyl) phosphorodithioate.

USDA-ARS personnel, had an electric control to regulate lag between oscillations, thereby controlling rainfall intensity. Its design (U.S. Dept. of Agriculture, 1986) is similar to those described by Meyer and Harmon (1979). Plot size was 76 cm by 76 cm for the conventional field and 96 cm by 96 cm for the alternative field because of difference in row spacing. There were two small plots at each sampling site, providing four measurements for each soil in each field.

We estimated runoff by sampling at fixed intervals beginning 5 minutes after surface runoff began, and continuing at 5 minute intervals until a constant runoff rate was achieved. Steady-state infiltration was calculated using application intensity minus the constant runoff rate. We also measured surface soil bulk density, using 7.6 cm cores collected with a Uhland sampler. At each sampling site we took 8 samples from within the corn row and 8 from between the rows.

1991 studies

Because of the 5 year rotation on Thompson's fields, in 1991 the alternative system and conventional system corn fields were diagonal to each other (Fig. 1). Mr. Snyder applied anhydrous ammonia to the conventional field at 166 kg N/ha in November 1990. A field cultivator was used to prepare a seedbed and to incorporate broadcast N-P-K fertilizer (35-90-112 kg/ha) and herbicide in May 1991. Pioneer Brand 3417 hybrid corn was planted on 11 May 1991, and the crop was cultivated once on 20 June 1991.

On 28 May, Mr. Thompson planted Asgrow 788 hybrid corn into the field, on which manure and municipal sludge had been applied at 34 Mg/ha three days earlier. Estimated N-P-K content of this ma-

terial was 8.5-4.8-2.9 kg/Mg (Rodale Institute, 1990), which provided N-P-K at 289-163-97 kg/ha. Weeds were controlled by rotary hoeing on 9 June, cultivating from 12 to 16 and on 24 June, and reforming ridges on 3 July. Rainfall was 132 mm in May, 93 mm in June, and 5 mm in July before the measurements. On 28 July, 20 mm of rain fell.

From 23 July to 2 August 1991 we used small single ring and tension infiltrometers (Ankeny et al., 1988), and a double ring infiltrometer and rainfall simulator for Webster and Clarion soils. A different rainfall simulator was used in 1991, a trailer transported rainfall simulator built after the design of Onstad et al. (1981). Raindrops were formed by 384 0.069-cm ID stainless steel dropper tubes spaced 7.6 cm apart in a 16 by 24 grid. A uniform rainfall intensity of 60 mm/hr was maintained for the 60 minute duration of each run.

We ran the rainfall simulator from 23 to 29 July on two plots for each soil on each farm (plot size 91 cm by 152 cm). Runoff from the plots was measured with a computer-read tipping bucket in a pit and corroborated with a water-stage recorder on the water collection tank. Infiltration was computed by determining the slope of the runoff versus time curve for minutes 51 through 60 by linear regression, and subtracting this value from the applied rainfall intensity.

Two double ring infiltrometer tests were run near each rainfall simulator plot from 30 July to 2 August. The inner ring was 30 cm diameter, and the outer was 60 cm diameter. Because the plots had been disturbed by removing forms for rainfall simulation runs, the rings were put in 150 cm from either end of the plot, one row from the center (northwest and southeast)

For each run we obtained four bulk density samples within the wetted areas after rainfall and double ring infiltration. The samples (3.1 cm diameter by 15 cm deep) were random with respect to row position.

We used time domain reflectometry (TDR) to determine volumetric soil moisture contents after the rainfall simulator runs (Topp and Davis, 1981; Dasberg, 1985; Baker and Lascano, 1989). Waveguides were inserted vertically 30 cm into the wet soil, with four measurements taken per rainfall simulator run.

On 23 and 24 July we made four small single ring ponded infiltration measurements (7.6 cm ring, Prieksat et al., 1992) near the same locations for the rainfall simulator and double ring measurements, but confined to the row between plants. These were followed by tension infiltration measurements on the same spot at -3, -6, and -15 cm pressure head. Tension infiltrometers exclude water flow in the largest pores with equivalent diameters greater than 1, 0.5, and 0.2 mm, for pressure heads of -3, -6, and -15 cm, respectively. This results in slower infiltration as pressure head is set more negative. The difference in infiltration between two pressure heads gives an indication of the amount of water flowing in pores in a given size range. Percent air-filled porosity was calculated as described by Wilson and Luxmoore (1988). Percent air-filled porosity is equivalent to the volume of macropores larger than a given cutoff diameter.

Runoff, steady-state infiltration, and bulk density data from each site in 1989 were analyzed using the Wilcoxon-Mann-Whitney nonparametric test (Steel and Torrie, 1980). The same procedure was used for 1991 data on runoff, steady-state infiltration, double ring infiltration, single ring infiltration, tension infiltration, bulk density, soil moisture content, and air-filled porosity at pressure heads of -3, -6, and -15 cm. Each data set had two locations for each of two soils for each farming system, although the number of determinations within location varied with type of measurement. Means (geometric for hydraulic properties, arithmetic for other measurements) were determined for each location, and differences between farming systems were determined from these means separately for each soil. The two locations for each soil functioned as two replicates.

Differences were considered significant at the 0.06 probability level. Statistical inference was weak because there were only two locations within each soil and farming system. With only two locations, using the Wilcoxon-Mann-Whitney rank test, it is not possible to have a probability level less than 0.06.

Results

Mean runoff and steady-state infiltration measurements for 1989 showed that runoff from Clarion was more than twice as high under the conventional farming practices compared with alternative practices that included ridge-tillage (Table 2). Mean runoff from Canisteo was slightly but not significantly higher for conventional farming practices. Similarly, the sprinkler infiltration rate was significantly higher for the alternative system only on Clarion soil.

Soil bulk density in the row (1989) was significantly lower for the alternative system on both Clarion and Canisteo soils (Table 2). Soil bulk density between rows was slightly but not significantly higher for the alternative system because soil from between the rows was moved to the ridges, and wheel traffic occurred in every other row.

Mean runoff in 1991 was significantly higher for the conventional system on both soils (Table 2), but rainfall simulator rates and single ring infiltration rates were significantly higher for the conventional system only on Webster soils. No significant differences between farming systems were apparent for double ring infiltration rates, but the trends were the same as for the other infiltration tests. Recent ridge reformation in 1991 may have contributed to faster infiltration for the alternative system.

Differences between years were apparent. In 1989, differences in infiltration rates between systems were higher on the well-drained Clarion soil, but in 1991 they were higher on the poorly drained Webster soil (Table 2). Runoff rates were very small in 1991 compared with 1989, and 1991 simulated rainfall infiltration rates were similar for both soils and farming systems. The drier soil in 1991 contributed to the differences in infiltration rates between the two years. On Webster soils, the simulated rainfall infiltration rate was lower than the double ring infiltration rates (Table 2). This implies that higher rainfall rates should have been used, but equipment limitations prevented higher rates.

Infiltration rates at a head of -3 cm were significantly higher for the alternative sys-

Table 2. Differences between two farming systems within two map units for infiltration and associated measurements.

	Clarion			Canisteo/Webster[1]		
	Conventional	Alternative	p[2]	Conventional	Alternative	p
1989						
runoff (μm/s)	9.05	4.17	0.06	4.17	3.82	0.22
sprinkler infilt. (μm/s)	8.7	13.6	0.06	13.6	14.0	0.22
bulk density (Mg/m^3)						
between rows	1.47	1.53	0.22	1.20	1.31	0.22
in rows	1.41	1.14	0.06	1.21	1.01	0.06
1991						
runoff (μm/s)	0.40	0.21	0.06	0.44	0.04	0.06
rainfall simulator (μm/s)	16.3	16.5	0.34	16.2	16.7	0.06
double ring (μm/s)	15.4	15.1	0.50	26.8	47.5	0.22
single ring (μm/s)	56.6	69.8	0.50	117.9	272.4	0.06
-3 cm infilt. (μm/s)	9.06	17.12	0.06	8.99	9.45	0.50
-6 cm infilt. (μm/s)	6.42	10.65	0.06	6.23	4.81	0.06
-15 cm infilt. (μm/s)	2.47	2.36	0.22	2.04	0.66	0.22
air % at -3 cm	1.54	1.25	0.50	1.99	4.44	0.06
air % at -6 cm	1.77	1.85	0.22	2.21	4.78	0.06
air % at -15 cm	3.59	5.16	0.50	4.23	6.66	0.06
TDR moisture (%)	15.1	14.7	0.06	9.85	24.9	0.06
bulk density (Mg/m^3)	1.57	1.44	0.22	1.42	1.44	0.22

[1] Predominantly Webster soils in 1989; exclusively Webster in 1991. In both cases, Webster occurred as inclusions in Map Unit 507 (Canisteo) in the published soil survey.

[2] Indicates probability level for differences between farming systems within a given map unit, according to the Wilcoxon-Mann-Whitney test.

tem on Clarion soil (Table 2); infiltration rates at a head of -6 cm were significantly higher for the conventional system on Clarion soil, but significantly higher for the alternative system on Webster soil. Percent of large pores was higher for the alternative system only on Webster soils. The greater macroporosity was probably due to a combination of factors: extensive soil stirring when the ridges were being formed; several years of accumulated organic matter, which results in stable aggregates (Jordahl and Karlen, 1993); and increased earthworm activity (Berry and Karlen, 1993). Both soils were significantly wetter for the alternative than the conventional system after the rainfall simulator runs, but bulk density was not significantly different between the two systems (Table 2).

Rainfall simulators cover a larger area and are considered more representative of infiltration than ring methods. Steady-state double ring measurements are assumed to measure saturated hydraulic conductivity directly. Infiltration rates for small single ring infiltrometers were higher than for other infiltration methods because measurements were only made in the row instead of being averaged over row and interrows (some of which have been trafficked), and because the 3-D flow from a small single ring did not convert easily to 1-D Ksat (due to theoretical difficulties). Preliminary small single ring measurements in 1989 showed that infiltration rates in the ridge-till row were even higher than in the nontrafficked interrows (data not shown). Even though the magnitude of the small single ring measurements was not comparable with other infiltration measurements, they were useful for comparison and did not disturb as large an area as rainfall simulation measurements. Small single ring measurements are considered too variable to represent the soil's infiltration rate adequately; however, when confined to specific regions, small ring infiltration measurements had coefficients of variation of 70%, compared to 80% for the larger double ring system.

Infiltration measurements have not been extensively used to compare farming systems. Rather, they are used to examine compaction due to wheel traffic (Ankeny et al., 1990) or heavy axle load (Logsdon et al., 1992), or to examine tillage differences (Mukhtar et al., 1985; Heard et al., 1988; Pikul et al., 1990; Zuzel et al., 1990).

Conclusions

We used various infiltration measurements to assess differences in water flow caused by two farming systems. Simulated rainfall infiltrometers should rain at a

fast enough rate to compare infiltration differences adequately when the soil is dry. Small single ring infiltrometers were adequate for comparing infiltration rates of the two farming systems even though the measurement area was small. Variability was reduced by confining readings to specific locations, that is, within rows and between plants. The C.V. for the single ring infiltrometer was less than for the much larger double ring infiltrometer.

Although we examined only two locations per soil and farming system, we observed statistically significant differences between farming systems on the Webster soil in 1991: the alternative field had significantly higher infiltration, greater macroporosity, and less runoff in the surface layer than the conventional field. The pattern was similar for the Clarion soil, but the differences were not significant. Increased infiltration resulted in greater volumetric water content for the alternative system after sprinkler infiltration of both soils. Infiltration rates at a head of -15 cm were not different between farming systems, showing that they were similar in the number and continuity of smaller pores. Preliminary results in 1989 suggested that runoff was significantly different between the farming systems only on the Clarion soil. Bulk density in the row was lower for the alternative system.

Acknowledgments. We thank Mr. and Mrs. Richard Thompson, Mr. and Mrs. Eugene Baker, Mr. and Mrs. David Snyder, and Mr. and Mrs. Steve Snyder for allowing us to interrupt their farming operations to conduct this investigation.

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Comparison of alternative farming systems. II. Earthworm population density and species diversity

Edwin C. Berry and Douglas L. Karlen

Abstract. *Effects of soil fauna on soil quality are largely unknown. Our objective was to learn whether long-term soil management has significantly affected earthworm species and populations at two Iowa locations. Soil cores were collected in fall 1989, spring 1990, and fall 1990 from a long-term tillage study in Polk County, Iowa, involving monoculture of corn (*Zea mays *L.) with either no-tillage, fall disking, fall chisel plowing, or fall moldboard plowing. Species found were* Lumbricus terrestris *(L.),* Octolasion tyrtaeum *(Savigny),* Aporrectodea trapezoides *(Dugés),* A. turgida *(Eisen), and* A. tuberculata *(Eisen), with* O. tyrtaeum *dominant across all treatments. As the amount of tillage increased, the number of earthworms generally decreased. In Boone County, Iowa, we compared the populations of mature and immature earthworms and cocoons on two adjacent fields, one managed conventionally, the other managed with an alternative farming system for more than 20 years. The predominant species was* A. tuberculata. *Regardless of management practice, the most worms were found in Canisteo soil on the toeslope landscape position.*

Key words: soil quality, crop rotation, earthworms, tillage, alternative agriculture, organic amendments

Introduction

Increased use of conservation or reduced tillage and greater awareness of alternative farming systems have raised many questions about how the soil fauna affects soil quality. Tillage interacts with soil fauna in important ways because it alters soil and crop residue conditions (Gregory and Musick, 1976). As tillage decreases, decomposition of crop residues slows and microenvironments are created that are favorable for the soil fauna (House and Stinner, 1983). Comparisons between no-tillage and conventional tillage have shown that as tillage decreases, there is an increase in the populations of ground beetles (House and All, 1981), spiders (Blumberg and Crossley, 1983), and earthworms (Barnes and Ellis, 1979; De St. Remy and Daynard, 1982; Edwards and Lofty, 1982; Clutterbuck and Hodgson, 1984; House and Parmelee, 1985; Mackay and Kladivko, 1985).

Earthworm activity has been shown to reduce surface crusting (Kladivko et al., 1986), hasten decomposition of crop residue mats (Zachmann and Linden, 1989), and alter the susceptibility of soils to water erosion in the north central U.S. (Zachmann et al., 1987). The quality and position of residues influence growth of earthworms, the amount of soil they ingest, and the number of burrows (Evans and Guild, 1948; Martin, 1982) and of openings to the surface (Zachmann et al., 1987). One negative consequence of earthworm activity is that continuous burrows (macropores) can affect solute transport and increase the potential for rapid movement of surface-applied agricultural chemicals through the soil profile (Tyler and Thomas, 1977; Barraclough et al., 1983; Edwards et al., 1989;

Earthworm species have been surveyed in different Midwestern cropping systems, but the results are incomplete. In Indiana, *Lumbricus rubellus* Hoffmeister, *Aporrectodea turgida* (Eisen), *Octolasion lacteum* (Savigny), *Eisenia rosea* (Savigny), and *L. terrestris* (L.) have been reported in reduced tillage systems in corn (*Zea mays* L.) and soybean (*Glycine max* [L.] Merr.) (Mackay and Kladivko, 1985). In Minnesota, *L. rubellus* and *A. tuberculata* (Eisen) were the species most often found in corn fields (Zachmann et al., 1987). Our objective was to learn whether long-term soil management practices have significantly affected earthworm species and populations in central Iowa.

Materials and Methods

Tillage study

We evaluated tillage effects on earthworms in monoculture corn plots established in 1977 on the Clarion-Nicollet-Webster soil association at the Iowa State University Ankeny Research Farm in Polk County. Tillage systems consisted of: 1) fall moldboard plow; 2) fall chisel plow; 3) fall disk tillage; and 4) no-tillage. Each plot was 0.4 ha (1 acre), and all treatments were arranged in a randomized complete block design with three replicates. Secondary tillage for seed bed preparation in the tilled treatments consisted of two passes with a field cultivator before planting. Weeds were controlled with incorporated applications of atrazine (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) and alachlor (2-chloro-2′-6-diethyl-N-

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Edwin C. Berry is Research Entomologist and Douglas L. Karlen is Soil Scientist, USDA-ARS, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011.

[methoxymethyl]-acetanilide). In no tillage plots, atrazine, alachlor, and paraquat (1:1-dimethyl-4,4′-bipyridinium [cation] dichloride) or glyphosate (N-[phosphonomethyl] glycine) were surface applied. Nitrogen (168 kg/ha as 28% urea ammonium nitrate [UAN]) was surface applied each spring, while P (45 kg/ha) and K (67 kg/ha) were surfaced applied in fall. The fall disk system was discontinued in 1988 and converted to no-tillage.

We determined earthworm populations and species by collecting soil cores (200 mm in diameter by 450 mm in length) with a modified tractor mounted hydraulic sampler. Samples were collected from the tillage study in May before planting, and again in October. Six cores were collected from each plot, two along each of three transects spaced 6 m apart. Each core was positioned directly over a single corn plant. We collected and identified the species of all mature earthworms in each sample. Since cocoons and immature earthworms are difficult to identify, they were counted and placed in dark growth chambers at 15°C in a mixture of soil and partially decomposed horse manure, and allowed to mature before being identified.

We used analysis of variance to test for differences in numbers of earthworms among tillage treatments, with the data log-transformed to improve homogeneity of variance. However, nontransformed data are presented in all tables. Significantly different ($p<.05$) treatment means were separated by Tukey's multiple range test (SAS Institute, Inc., 1985).

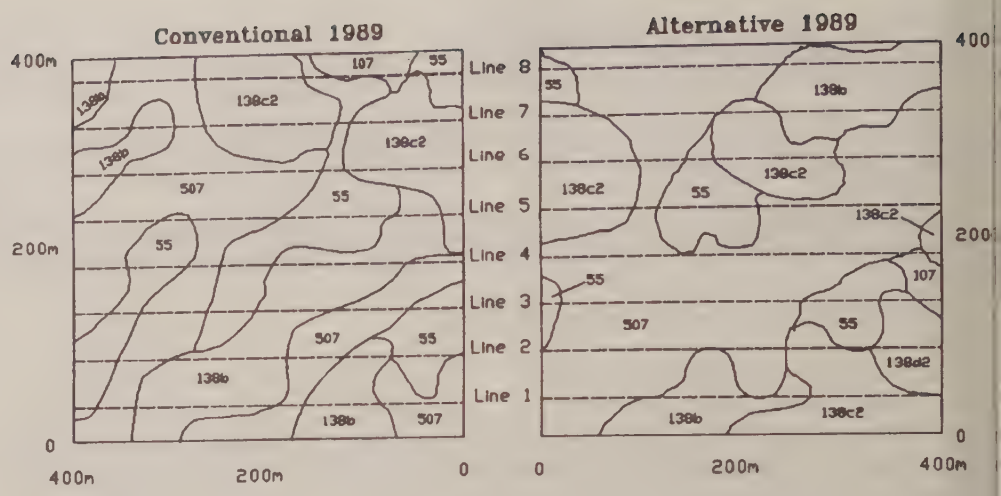

Figure 1. Site map and description of soils at the research site.

Soil indentification:

Soil Type	Map unit	Classification
Clarion loam		Fine-loamy, mixed, mesic Typic Hapludolls
2 to 5% slopes	138B	
5 to 9% slopes	138C2	(moderately eroded)
9 to 14% slopes	138D2	(moderately eroded)
Nicollet loam	55	Fine-loamy, mixed, mesic Aquic Hapludolls
Canisteo silty clay loam	507	Fine-loamy, mixed (calcareous), mesic Typic Haplaquolls
Webster silty clay loam	107	Fine-loamy, mixed, mesic Typic Haplaquolls

Farming systems study

We also sampled earthworms from an alternative/conventional on-farm research site in Boone County, Iowa. Sampling sites were on two adjacent 16 ha (40 acre) fields (Fig. 1). Long-term soil and crop management records (Logsdon et al., 1993) were obtained from cooperators to verify that farming practices were consistent for a sufficiently long period.

We recognize that in this approach, each farming system is practiced on the particular distribution of soils that happens to be found on the respective field; however, we needed to work on farmers' fields to get the long-term management histories and to do the study on a field scale. On farmers' fields, it is not possible to assign the treatments randomly. Therefore, specific treatment effects cannot unambiguously be separated from field effects using customary experimental designs and statistical analysis methods. By using map units to identify similar soils within each field, we can establish a semi-replicated design for comparing farming systems (Karlen and Fenton, 1991). The justification for this approach is presented by Logsdon et al. (1993).

This site has the additional problem of inclusions of Webster soils within Map Unit 507 ("Canisteo" in the published survey). In fact, the "Canisteo" samples are mainly from Webster soils (Logsdon et al., 1993). We partly eliminated the confounding effect of these inclusions by testing for free calcium carbonate in the samples analyzed for total carbon (see below).

Farming practices used by cooperators are described in detail by Logsdon et al. (1993). Conventional farming practices on the Baker farm consisted of a 2 year rotation of corn and soybean, using commercial fertilizer, including anhydrous ammonia. Alternative practices have been used on the Thompson farm for over 20 years (National Research Council, 1989, pp. 308-323). This system is based on a 5 year rotation of corn, soybean, corn, oat (*Avena sativa* L.) and mixed hay. Fertilization is with a mixture of animal manure and municipal sludge, and ridge-tillage with

rotary hoeing and cultivation are used to control weeds without herbicides.

We collected soil cores for assessing earthworm populations in October 1989 and September 1990 adjacent to line 6 (Fig. 1) from both farming systems. This provided a measure of earthworm activity in Clarion (138B), Nicollet (55), and Canisteo (507) soil map units. Coring procedures were the same as described earlier for the long-term tillage study. Samples were collected before fall tillage in both fields. In 1989, 30 cores were obtained from the southeast field (Field 1) on the Thompson farm (Fig. 1). We collected three cores, spaced approximately 6 m apart, at each of 10 positions located approximately 24, 48, 96, 144, 192, 240, 288, 336, 384, and 408 m from the boundary between the two farming systems (Fig. 1). In the conventional field, there were no earthworms or signs of earthworm casts or surface activity. After we extracted five cores from the conventional field, approximately 48, 144, 240, 288, and 336 m from the common boundary (Fig. 1), and had observed no burrows at the bottom of each core, we stopped sampling because it was beginning to interfere with the farming operation. In 1990, we collected 20 samples from each farming system. Immature worms and cocoons were handled as described previously.

Soil samples were collected in April 1989. A 50 mm soil core was taken with a hydraulic probe every 48.8 m along each of the eight transects (Fig. 1), beginning approximately 24 m from the common boundary between the farms. The soil map unit represented by each core was determined from the published soil survey map (U.S. Dept. of Agriculture, 1981). Each core was fractionated by horizon and analyzed for total-, NH_4- and NO_3-N (Karlen and Colvin, 1992). We analyzed carbon content because we hypothesized that the alternative practices would lead to higher soil organic matter levels, which would create a more favorable microenvironment for earthworms.

Subsamples from the soil cores corresponding to depths of 0 to 100, 100 to 200, 200 to 300, 300 to 450, and 450 to 600 mm were dried at 40°C, crushed to pass a 2 mm screen, and pulverized for 5 minutes in a ball mill before total carbon was measured by dry combustion with a Carlo Erba NA1500 NCS elemental analyzer (Haake Buchler Instruments, Inc., Patterson, N.J.). The soil samples were not pretreated to remove free carbonates, but samples suspected to have free carbonates were treated with dilute HCl. If the soil effervesced, the sample was not included in the computation of mean values. (Only a small proportion of the samples were excluded; recall that Map Unit 507, designated as "Canisteo" in the published survey, is predominantly Webster, which, unlike Canisteo, does not contain free calcium carbonate at the surface.) Grouping by depth increment, farming system, and soil map unit resulted in 3 to 35 data points for each mean.

Mean values for each combination of farming system, sampling depth and soil map unit were compared statistically using Proc TTEST (SAS Institute, 1985). A Cochran and Cox (1950) procedure was used to compute the probability that the means were significantly different, although that approach tends to be conservative (Lee and Gurland, 1975).

Results and Discussion

Tillage study

The lumbricids recorded in the tillage experiments consisted of *Lumbricus terrestris*, *Octolasion tyrtaeum*, *Aporrectodea trapezoides*, *A. turgida*, and *A. tuberculata* (Table 1). *O. tyrtaeum* was the leading species across all treatments (24.2% in fall 1989, 34.3% in spring 1990, and 30.5% in fall 1990).

Trends and differences in populations of earthworms are not easy to interpret. Differences in the total number of earthworms, across all species, between the no-tillage and disk systems were not significant ($p>0.05$) during any sampling period. However, during all sample periods there was a general pattern of lower populations with disking compared with no-tillage. Since the disk system is in transition from fall disking to no-tillage, similarities between the two systems are probably due to the increased food supply and lack of soil disturbance. During all sample periods, more earthworms were found in the systems with less tillage (disk or no-tillage as opposed to moldboard or chisel plowed). This supports the hypothesis of Edwards and Lofty (1982) that as tillage decreases, crop residues increase, in turn buffering weather changes and increasing the availability of food for earthworms. In the fall 1989 and spring 1990 samples, there were significantly ($p<0.05$) more earthworms in the no-tillage than in the chisel plots, but differences among the disk, chisel, and moldboard plow systems were not statistically significant.

The general effects of tillage on earthworms are well documented, but tillage effects in corn monocultures are not clear. Mackay and Kladivko (1985) reported that tillage had little effect on earthworm populations in corn monocultures (16 m^{-2} with no-tillage, compared with 8 m^{-2} with conventional tillage). However, in soybean monoculture, no-tillage raised the number of earthworms to 141 m^{-2}, from 62 m^{-2} with conventional tillage. Similar results were reported by De St. Remy and Daynard (1982) for no-tilled (48 m^{-2}) and tilled corn (55 m^{-2}). Lack of response to tillage and the low total number of earthworms in both studies were hypothesized to be related to the quantity and quality of residues and to the use of insecticides (terbufos and phorate) and anhydrous ammonia fertilizer.

Unfortunately there is a tendency to refer to "earthworms" in general, rather than to specific species. Based on differences in feeding and burrowing habits (Bouché, 1977), the lumbricids found in our study were classified into three distinct types. The first consisted of *L. terrestris*, which feed on plant and animal residues at the soil surface and maintain a permanent vertical burrow system. The second consisted of *A. trapezoides*, *A. tuberculata*, and *A. rosea*. These species feed below the surface on more decomposed residue and have horizontally oriented burrows that are not permanent. The final type was *O. tyrtaeum*, which feed below the surface on residue that is in an advanced state of decomposition. Burrows are horizonal and are not permanent.

Tillage effects in this study differed among species. For example, in the 1989 fall samples, significantly ($p<0.05$) more *L. terrestris* and *A. trapezoides* were found

Table 1. Tillage system effect on mean number[1] of earthworms per m^2, by species.

Tillage system	*Lumbricus terrestris*	*Octolasion tyrtaeum*	*Aporrectodea trapezoides*	*Aporrectodea turgida*	*Aporrectodea tuberculata*	Total
			Fall 1989			
No tillage	36.0a[2]	42.8a	56.5a	37.7a	18.9a	191.9a
Disk	10.3ab	46.3a	22.3ab	15.4a	17.1a	111.4ab
Chisel	6.8b	3.4a	1.7b	5.1a	17.1a	34.1b
Plow	10.3ab	6.8a	15.4ab	12.0a	29.1a	73.6ab
			Spring 1990			
No tillage	58.2a	72.0a	20.6a	18.9a	20.6a	190.3a
Disk	15.4a	48.0a	29.1a	12.0a	27.4a	131.9ab
Chisel	12.0a	12.0a	1.7a	3.4a	10.3a	39.4b
Plow	10.3a	15.4a	8.6a	10.3a	24.0a	68.6ab
			Fall 1990			
No tillage	20.6a	48.0a	25.7a	22.3a	13.7a	130.3a
Disk	12.0a	27.4a	12.0a	3.4a	36.0a	90.8ab
Chisel	5.1a	12.0a	5.1a	1.7a	22.3a	46.2a
Plow	3.4a	5.1a	5.1a	6.8a	15.4a	35.8b

[1] Statistical analysis and mean separations were performed on log transformed data, but the means are shown nontransformed.
[2] Means followed by the same letter within a column within a sample period are not significantly different (p=0.05, Tukey's range test).

in the no-tillage system than in the chisel system. *A. tuberculata* was least affected by tillage. Although significant differences were not obtained for all species, higher numbers of *O. tyrtaeum* and *A. turgida* were also found in systems with the least tillage.

Farming systems study

The lumbricids recorded in the alternative farming experiment consisted of *L. terrestris*, *A. trapezoides*, *A. rosea*, and *A. tuberculata*. More earthworms were found on the alternatively-managed field (Table 2). The predominant species in this field in 1989 was *A. tuberculata* (92.2%), followed by *A. trapezoides* (4.6%), and *L. terrestris* (2.7%). These are the predominant lumbricid species throughout the northern Corn Belt. Introduction of earthworms has been suggested as a method for improving soil quality, but this was never done on either of these fields. A laboratory study using soil from both fields (data not presented) confirmed that if a food source such as manure was added, various lumbricids could survive and reproduce in soil from either farm. These observations confirmed our hypotheses that crop residues, manure, or other organic materials that provide a food source and a favorable microenvironment are the primary factors required to sustain and increase earthworm populations in these soils.

The number of earthworms in the alternative field decreased nearly fivefold between 1989 and 1990, but *A. tuberculata* was again the predominant species (88.3%). The population measured in 1990 was similar to that found in the long-term tillage study and to the values reported in the literature (De St. Remy and Daynard, 1982; Mackay and Kladivko, 1985). We hypothesize that the high population measured in 1989 resulted from three consecutive years of ridge-tillage practices, with an annual application of 45 Mg/ha of manure plus municipal sludge. This treatment presumably provided an abundant food source. The reduction in earthworm populations in the alternative field between 1989 and 1990 was probably caused in part by fall and spring tillage, which included multiple passes with an offset disk to prepare the field before seeding the oat-legume-grass mixture. This tillage presumably decreased soil water content, hastened decomposition of surface residues, and physically damaged most earthworms feeding near the soil surface.

The most earthworms were found in the Canisteo soil in 1989. This series occurs in the toeslope position, and generally is higher in soil water and carbon content. Earthworms were also found in both years on the hilltops (Clarion soil) in the alternative field. In 1989, the conventional field showed no evidence of earthworm castings, surface activity, or burrows at the bottom of the core samples. Although we took fewer soil cores there, we are confident that

Table 2. Mean earthworm populations (m^{-2}) in 1989 and 1990 on two central Iowa farms.

Soil Series	1989		1990	
	Conventional	Alternative	Conventional	Alternative
Clarion (138B)	0.0	579.7	0.0	80.6
Nicollet (55)	0.0	269.7	0.0	0.0
Canisteo (507)	0.0	837.0	9.3	127.1

the number of worms was much lower in the conventional than in the alternative field (but probably not zero).

Samples collected in the alternative field in 1990 again contained more worms in the Canisteo soil than in either the Nicollet or Clarion. Also, the only location where earthworm activity was evident in the conventional field was in the Canisteo soil.

Total carbon content of samples collected from four soil map units along the eight transect lines (Fig. 1) was higher in the top 450 mm of the alternative field than in the conventional field (Table 3). The differences were consistent, even for the Canisteo silty clay loam, which had the highest total carbon content but may have had some undetected free calcium carbonate. Statistically, however, differences in total soil carbon between farming systems were significant at $p<0.1$ for only 3 of 16 comparisons in the top 450 mm (Table 3). The lack of statistically significant differences, except in the top 100 mm, may reflect the difficulties in increasing the carbon concentration in soils that already are high in soil organic matter. However, we do not think that this lack of statistical difference in soil carbon concentrations refutes our initial hypothesis that the addition of 45 Mg/ha of manure and municipal sludge during each of the first three years of every 5 year rotation increased the food supply across all soil map units and thus created a more favorable environment for earthworm survival and reproduction.

Table 3. Total carbon concentrations (g/kg) in four Central Iowa soils after 20 years of alternative soil and crop management practices.

Soil Map Unit	Alternative			Conventional			p[1]
	n	Mean	SE	n	Mean	SE	
0 to 100 mm							
138B	6	22.4	2.6	6	18.5	1.8	0.273
138C2	15	22.7	2.1	9	13.4	1.9	0.008
507	22	41.5	2.3	22	34.8	2.9	0.085
55	7	36.4	4.2	18	22.5	1.8	0.020
100 to 200 mm							
138B	8	23.4	4.9	4	19.4	2.8	0.516
138C2	14	18.1	1.9	8	12.9	2.3	0.117
507	24	40.0	2.9	21	36.9	3.4	0.490
55	6	30.3	5.0	9	24.3	4.1	0.390
200 to 300 mm							
138B	6	21.1	4.9	3	12.7	2.2	0.196
138C2	10	19.6	2.3	7	12.9	2.7	0.108
507	20	33.0	2.9	22	31.1	2.9	0.642
55	5	29.6	4.7	16	21.9	3.2	0.232
300 to 450 mm							
138B	9	21.3	2.3	9	15.5	2.8	0.150
138C2	21	14.8	1.7	12	11.7	3.1	0.389
507	36	24.9	2.0	25	23.8	3.2	0.768
55	8	20.0	3.5	24	14.4	1.6	0.189
450 to 600 mm							
138B	10	20.3	3.7	7	7.6	1.2	0.011
138C2	17	10.7	1.2	9	11.6	3.2	0.807
507	35	14.0	1.2	26	15.7	2.2	0.500
55	8	13.0	2.0	18	9.2	1.0	0.140

[1] Probability of the two farming system means being significantly different as determined by a Cochran and Cox (1950) t-test.

Summary and Conclusions

This study provides quantitative information on how tillage and an alternative management system affect earthworm

species and populations at two sites for soils in the Clarion-Nicollet-Webster soil association in central Iowa. The lumbricids were different at the two locations. *L. terrestris*, *A. trapezoides*, *A. tuberculata*, *A. turgida*, and *O. tyrtaeum* were present at the tillage experiment (Polk County) site, with *O. tyrtaeum* the dominant species. *L. terrestris*, *A. trapezoides*, *A. tuberculata*, and *A. rosea* were found at the Boone County location, with *A. tuberculata* dominant. We found higher earthworm populations where minimum tillage and alternative soil and crop management practices were used. Our results show that earthworm populations can be influenced by farming practices, but additional data will be needed to quantify how residue management and additions of organic amendments affect earthworm populations.

Temperature, moisture, and food source, all of which are affected by tillage, are among the factors reported to influence earthworm populations. However, before we can understand how tillage influences the biological components of soil, such as earthworms, additional studies are needed on rates of residue decomposition at different locations in the soil, and on the role of crop residue in maintaining a stable environment within the biologically active zone.

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Comparison of alternative farming systems. III. Soil aggregate stability

J.L. Jordahl and D.L. Karlen

Abstract. *Quantitative studies are needed to separate the real and supposed benefits of alternative farming practices. Our objective was to learn how conventional and alternative practices on adjacent farms in central Iowa affected the water stability of soil aggregates. We collected samples of Clarion loam (fine-loamy, mixed, mesic Typic Hapludoll) from adjacent 16 ha fields in fall 1990 and spring 1991. Aggregate stability was determined by wet-sieving and by measuring turbidity of soil-water suspensions. The combined effects of alternative practices resulted in greater water stability of soil aggregates, higher soil organic matter content, and lower bulk density compared with conventional practices. The components of the alternative system that were mainly responsible for these differences were: rotations that included oat and hay crops; ridge-tillage; and additions of 45 Mg/ha of a mixture of animal manure and municipal sludge during the first 3 years of each 5 year rotation. The more favorable soil physical conditions, shown by increased water stability of soil aggregates, presumably will improve soil water regimes and reduce long-term soil erosion losses from the alternatively managed fields.*

Key words: corn, soybean, alternative agriculture

Introduction

Soil quality and tilth are frequently reported to be improved under alternative farming practices involving crop rotations and applications of organic matter. Reganold et al. (1987) found greater soil organic matter content, lower modulus of rupture, thicker A horizons (topsoil), and less water erosion on an organically managed farm compared with a conventional farm. In Ohio, Jackson (1988) compared soils on Amish farms with those on neighboring farms where continuous no-till corn was being grown. The Amish farmers used a crop rotation that included hay, applied manure and straw, and tilled conventionally (moldboard plow). She found that soils on the Amish farms had higher infiltration rates, higher organic matter levels, and lower bulk densities than did soils on no-till farms.

Studies evaluating tillage and crop rotation effects on soil physical properties often focus on soil aggregation, because increasing tillage intensity and decreasing use of hay or meadow crops can decrease water stability of soil aggregates. Douglas and Goss (1982) and Bruce et al. (1990a) reported that aggregate stability was greater with chisel and no-till than with moldboard plowing. Wilson and Browning (1945) reported that the stability of soil aggregates was lowest in continuous corn fields, and that it increased progressively for rotation corn (*Zea mays* L.), rotation oats (*Avena sativa* L.), continuous alfalfa (*Medicago sativa* L.), and continuous bluegrass (*Poa pratensis* L.).

The level of soil organic matter has been associated with aggregate stability, because as soil organic matter decreases stability of soil aggregates usually decreases (Tisdall and Oades, 1982; Chaney and Swift, 1984; Pojasok and Kay, 1990). The combination of regular cultivation and low organic matter inputs decreases soil organic matter and soil aggregate stability (Oades, 1984). Application of manure increased aggregate size and stability in continuous corn (Weill et al., 1988).

Bruce et al. (1990b) reported that soil carbon and aggregate stability at a given soil depth depended on soil texture, crop species, and tillage method. They found that soil characteristics that sustained infiltration and reduced erodibility were maintained better by leaving crop residues on the soil surface with no tillage than by disking before planting. Luk (1979) found that water stability of aggregates was the most significant variable for explaining soil erosion. Infiltration and soil erosion were highly correlated with several measures of soil aggregate stability (Miller and Baharuddin, 1986).

Our primary objective was to compare the long-term effects of alternative and conventional farming practices on physical properties of soils on two adjacent central Iowa farms. We focused on water stability of soil aggregates as the primary means of comparison.

Methods and Materials

We collected soil samples from adjacent 16 ha (40 acre) farm fields located on the Des Moines lobe near Boone, Iowa. Long-term soil and crop management records (Logsdon et al., 1993) were obtained from

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J.L. Jordahl is District Conservationist, USDA-SCS, 100 8th Street South, Humboldt, IA 50548. D.L. Karlen is Soil Scientist, USDA-ARS, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011.

cooperators to verify that farming practices were consistent for a sufficiently long period.

We recognize that in this approach, each farming system is practiced on the particular distribution of soils that happens to be found on the respective field; however, we needed to work on farmers' fields to get the long-term management histories and to do the study on a field scale. On farmers' fields, it is not possible to assign the treatments randomly. Therefore, specific treatment effects cannot unambiguously be separated from field effects using customary experimental designs and statistical analysis methods. By using map units to identify similar soils within each field, we can establish a semi-replicated design for comparing farming systems (Karlen and Fenton, 1991). The justification for this approach is presented by Logsdon et al. (1993).

Farming practices used by both cooperators are described in detail by Logsdon et al. (1993). Conventional farming practices on the Baker farm involve a 2 year rotation of corn and soybean (*Glycine max* [L.] Merr.), using commercial fertilizer, including anhydrous ammonia. Alternative practices on the Thompson farm (National Research Council, 1989, pp. 308-323) are based on a 5 year rotation of corn, soybean, corn, oat and mixed hay. Fertilization is with a mixture of animal manure and municipal sludge. Ridge-tillage with rotary hoeing and cultivation are used to control weeds without herbicides. This study was undertaken because two survey samplings of Nicollet (fine-loamy, mixed, mesic Aquic Hapludolls) and Clarion soils suggested that soil aggregates from the Thompson farm were more stable in water than aggregates from the Baker farm (Jordahl, 1991).

We sampled soils from two fields for each farming system following grain harvest in October 1990. Our objective was to compare long-term, integrated farming system effects. Samples were from Clarion soil map units (138C2, 5-9% slopes, moderately eroded) in all fields. Soil map unit boundaries were determined by hand probing. The current crop was either corn (ALT-CORN or CONV-CORN), hay (ALT-HAY), or soybean (CONV-SOY). Sixteen samples were collected randomly from each field, except for ALT-CORN, where only eight samples were collected because of the small area.

The samples, which were 15 cm by 15 cm by 7.5 cm deep, were excavated using a hand trowel and passed through a screen with 6.35 mm openings. Half of each sample was air dried at ambient temperature (25°C). The other half was maintained in a field-moist condition by refrigerating it at 4°C in a sealed plastic container.

We measured water stability of air-dry soil aggregates using the Kemper and Rosenau (1986) method, which includes pre-wetting the soil aggregates with water vapor. Pojasok and Kay (1990) suggested that measurements of air-dry aggregate stability may lead to misleading conclusions because only the top few mm of soil are ever air dry. Therefore, we also measured the stability of field-moist samples using the same procedures as for air-dry aggregates.

We collected a second set of samples in spring 1991, after corn and soybean were planted in both the CONV and ALT fields. To reduce the variation among samples from a single map unit, we selected two closely matched sites of Clarion loam in each field. Criteria used were: 13-18 cm of mollic epipedon, no free carbonates as determined by examining for effervescence after adding dilute HCl, subsoil colors that indicate good drainage, and a gently sloping ridgetop position. Sites were selected in two fields from each farming system. The ALT-CORN field was first year corn following hay, while ALT-SOY was soybean following corn, two years after hay. The CONV-CORN and CONV-SOY fields sampled in 1991 were the same fields as were sampled in 1990, but their labels have been changed because of the annual crop rotation (that is, CONV-CORN in 1990 was CONV-SOY in 1991). We did not attempt to sample identical sites each year because of the differences in our site selection criteria.

Within each 16 ha field, two nearly identical Clarion soil map units were located several hundred meters apart. From within each map unit, we selected three sampling sites from adjacent rows. Samples 15 cm by 15 cm by 7.5 cm deep were excavated using a hand trowel. The total distance between samples within a map unit was approximately 3 m. With two sites in each of four fields, and with three samples per site, there were a total of 24 samples. Water stability of soil aggregates was determined by wet-sieving field-moist samples.

We also measured soil aggregate stability using a turbidimetric method based on the procedures described by Williams et al. (1966) and Molope et al. (1985). After vapor wetting 2.00 g (±0.05) of 1- to 4-mm field-moist soil aggregates, as described by Kemper and Rosenau (1986) for wet-sieve analysis of air-dry aggregates, each sieve cup was inverted over a funnel that was placed in a 200 mm by 25 mm culture tube. Soil remaining on the sieve cup was washed through the funnel using a small amount of distilled water. The tube was then filled with distilled water to a total volume of approximately 65 ml. To minimize any effects of differences in equilibration time, we removed samples from the vapor chamber for analysis in random sequence.

The culture tubes were stoppered and spun end-over-end on a spinning device (Jordahl, 1991) for 20 revolutions at approximately 20 rpm. After spinning, tubes were placed in a holder and a 5-ml aliquot was withdrawn from a depth of 2.9 cm, using a mechanical pipette after 3 min. We chose the time of pipetting somewhat arbitrarily, making slight adjustments for differences in water temperature. Particle diameter measured by this technique, based on the Stokes equation, was less than 0.0126 mm equivalent spherical diameter. Percent transmittance of the sample was determined at a wavelength of 620 nm. A 100% transmittance baseline was established using distilled water. We did not correct samples for sand content in the turbidimetric procedure.

Soil organic matter was measured for the 1 to 4 mm aggregate fraction using a Carlo Erba NA1500 NCS elemental analyzer (Haake Buchler Instruments, Inc., Patterson, N.J.) to measure total C and N concentrations. Particle size was determined using the pipette method (Walter et al., 1978) for the fall 1990 samples and the hydrometer method (Gee and Bauder, 1986) for the spring 1991 samples. Soil bulk density was measured by collecting 75 mm by 75 mm soil cores with a Uhland sampler and drying the samples at 104°C

until they maintained a constant weight. We took all aggregate samples and bulk density cores from an area centered on the planted row. The exact spot from which the core was taken was chosen randomly. A total of six cores (three from each location) were taken in each field for bulk density determinations.

Mean values for variables measured for each farming system were compared statistically using Proc TTEST (SAS Institute, Inc., 1985). A Cochran and Cox (1950) procedure was used to compute the probability that the means were significantly different, although that approach tends to be conservative (Lee and Gurland, 1975).

Results

Aggregate stability

Field-moist and air-dry measurements of aggregate stability of samples collected during fall 1990 are shown in Table 1. For both methods, soil aggregates from the alternatively managed fields were significantly more stable than those from the conventionally managed fields (t-test, $p<.01$). Two of four comparisons between fields within the same farming system were not significant, with the other two significant at $p<0.05$. This confirms the known variation within a farming system, and presumably reflects known variation within soil map units. However, the magnitude and consistency of differences between farming systems are much greater, suggesting that the management system was having a greater effect than sample location.

When the samples were collected, soil water content was significantly ($p<0.05$) lower in conventional fields than alternative fields in three of four comparisons (Table 1). The fourth comparison showed the same pattern, but the difference was significant only at $p<0.12$. Differences between fields within a farming system were not statistically significant. Aggregates that are drier at sampling tend to be more stable (Churchman and Tate, 1987; Perfect et al., 1990). Thus, aggregates from alternative fields were more stable than those from conventional fields, even though they were wetter when sampled.

Table 1. Means and t-test levels of significance for Clarion loam sampled in fall 1990 from conventional (Baker) and alternative (Thompson) fields.

Field	N	Wet Aggregate Stability (%)		Carbon	Clay	Silt	Sand	pH	Gravimetric Water Content
		Field Moist	Air Dry	(g/kg)	(%)	(%)	(%)		(%)
CONV-CORN	16	48.6	79.9	14.6	16.4	27.3	56.4	6.5	13.4
ALT-CORN	8	78.3	89.3	26.0	17.4	30.9	51.7	7.3	15.9
		**[1]	**	**	NS	NS	NS	*	NS
CONV-CORN	16	48.6	79.9	14.6	16.4	27.3	56.4	6.5	13.6
ALT-HAY	16	67.1	87.6	20.6	15.4	26.3	58.3	7.3	17.2
		**	**	**	NS	NS	NS	**	**
CONV-SOY	16	49.8	76.1	11.7	12.8	22.8	64.4	7.2	11.6
ALT-HAY	16	67.1	87.6	20.6	15.4	26.3	58.3	7.3	17.2
		**	**	**	NS	NS	NS	NS	**
CONV-SOY	16	49.8	76.1	11.7	12.8	22.8	64.4	7.2	11.6
ALT-CORN	8	78.3	89.3	26.0	17.4	30.9	51.7	7.3	15.9
		**	**	**	**	*	*	NS	*
CONV-CORN	16	48.6	79.9	14.6	16.4	27.3	56.4	6.5	13.4
CONV-SOY	16	49.8	76.1	11.7	12.8	22.8	64.4	7.2	11.6
		NS	*	*	**	NS	*	NS	NS
ALT-CORN	8	78.3	89.3	26.0	17.4	30.9	51.7	7.3	15.9
ALT-HAY	16	67.1	87.6	20.6	15.4	26.3	58.3	7.3	17.2
		**	NS	*	NS	NS	NS	NS	NS

[1] In all tables, NS = non-significant; *, **, and *** indicate significance at $p < .05$, $p < .01$, and $p < 0.001$, respectively.

For ALT-CORN, where the preceding crop had been hay, water stability of field moist aggregates was 30% higher than for CONV-CORN, where the preceding crop was soybean. These measurements, which were made in the fall, show the importance of the preceding crop. They are also consistent with the findings of Laflen and Moldenhauer (1979) that in spring, soil erosion from corn fields following soybean was greater than from either corn or soybean fields following corn. Our aggregate stability observations also are consistent with the findings of Bruce et al. (1990b) that aggregate stability at a given soil depth depended on crop species, soil texture, and tillage.

Soil composition

Total carbon in the conventional fields averaged only 57% of the levels in the alternative fields, with all four comparisons significantly different ($p<0.01$). Differences between fields within a farming system also were significant ($p<0.05$), but the range was much lower.

Particle size analyses of samples collected in fall 1990 showed no significant differences for three of four comparisons between the two farming systems. CONV-SOY had significantly lower clay and silt, and higher sand than ALT-CORN. A comparison between fields from the conventional farming system showed that ag-

gregates from the CONV-CORN field had significantly higher ($p<0.01$) clay and significantly lower ($p<0.05$) sand content than aggregates from the CONV-SOY field. This difference may also have contributed to greater water stability of aggregates from the CONV-CORN, because aggregate stability is positively correlated with clay content (Luk, 1979; Bruce et al., 1990b; Pojasok and Kay, 1990).

Correlations among soil characteristics

Correlation analysis showed that both air-dry and field-moist wet aggregate stability were significantly correlated with total C, clay, silt, sand, and water content (Table 2). Aggregate stability was positively correlated with clay content and negatively correlated with sand content. Correlation coefficients between water stability and sand, silt, or clay were higher with air-dry than field-moist samples.

The relationship between aggregate stability and total C content for air-dry and field-moist aggregates is shown in Figure 1. The field-moist method appears to show greater response to C content than does the air-dry method. The figure also shows that aggregate stability is generally higher with air drying, especially for samples with low organic matter content.

The relationship between aggregate stability and clay content for the two methods of handling the aggregates is shown in Figure 2. In contrast to case of C content, the method of handling the soil aggregates has a much smaller effect on the relation between aggregate stability with clay content. Although the exact reason for this is not known, it may have been caused by a narrow range in clay content (12.8 to 17.4%) compared with the more than twofold range in total carbon (11.7 to 26 g/kg).

Turbidimetric and particle size analysis

Williams et al. (1966) and Molope et al. (1985) reported more success in distinguishing treatment differences with turbidimetric methods than with wet sieving. Therefore, for the spring 1991 sampling, we used field-moist soil aggregates for both wet-sieving and turbidimetric analysis of aggregate stability. Again, soil aggregates from the alternative farm were

Table 2. Simple correlation coefficients for the combined data sets from the conventional (Baker) and alternative (Thompson) fields sampled in fall 1990.

	FM-WAS[1]	Carbon	Clay	Silt	Sand	Water Content	pH
AD-WAS[1]	0.83 ***	0.79 ***	0.57 ***	0.54 ***	-0.58 ***	0.71 ***	-0.14 NS
FM-WAS		0.80 ***	0.38 **	0.43 **	-0.44 ***	0.50 ***	0.18 NS
Carbon			0.57 ***	0.55 ***	-0.59 ***	0.68 ***	-0.09 NS
Clay				0.75 ***	-0.88 ***	0.74 ***	-0.50 ***
Silt					-0.97 ***	0.61 ***	-0.45 ***
Sand						-0.70 ***	0.49 ***
Water Content							-0.40 **

[1] FM-WAS = Field-moist wet-aggregate stability.
AD-WAS = Air-dry wet-aggregate stability.

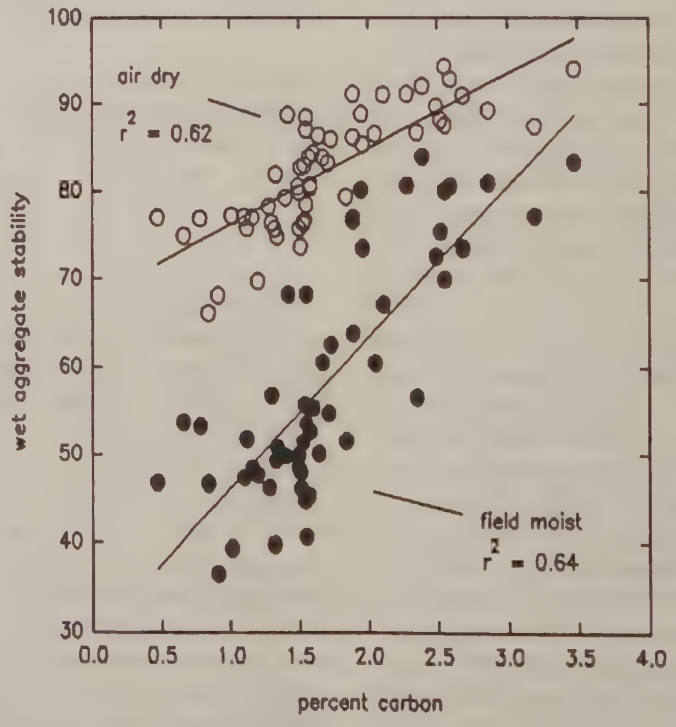

Figure 1. Relationships between wet aggregate stability and percent total C content for air-dry and field-moist samples collected during fall 1990. The regression equations were: $y = 67.54 + 8.65x$ for air-dry samples; $y = 29.00 + 17.18x$ for field-moist samples.

more stable, regardless of the crop or measurement technique (Table 3). For the corn fields, only the wet-sieving technique showed statistically significant differences. The transmittance (log %T) in the turbidimetric procedure showed the same patterns, but the differences between fields were not significant at $p<0.05$.

For the combined data set, transmittance (log %T) and wet sieve data were positively correlated (Table 4). Water stability of aggregates measured by wet sieving was highly correlated with total C, clay, silt, and sand content. The turbidimetric data were correlated with total C, clay and sand content.

Particle size analysis showed that soil from the CONV-CORN field had significantly higher sand content than soil from the ALT-CORN field. Total carbon analysis showed significantly ($p<0.01$) lower values for the conventional fields than for the alternative fields. Bulk density also was significantly higher and water content significantly lower ($p<0.01$) in CONV-CORN than the ALT-CORN.

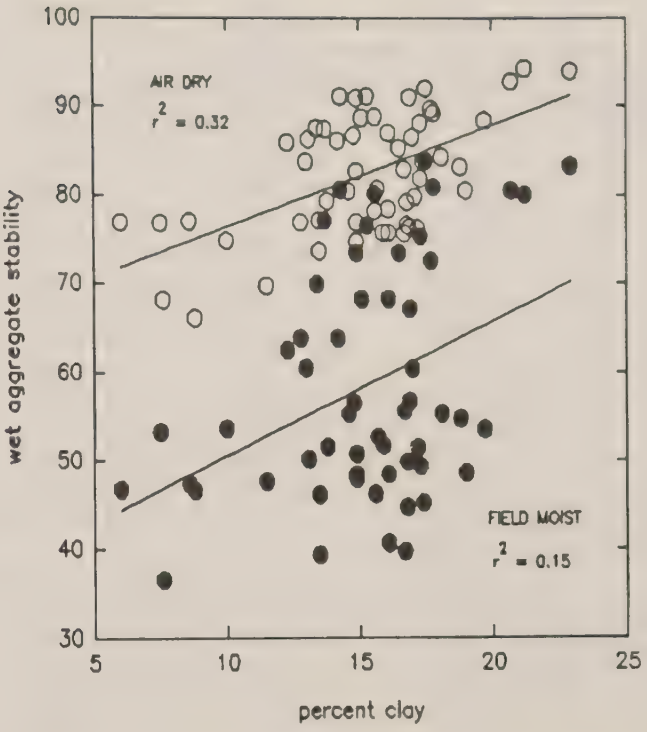

Figure 2. Relationships between wet aggregate stability and percent clay content for air dry and field moist samples collected during fall 1990. The regression equations were: y = 64.85 + 1.15x for air-dry samples; y = 35.30 + 1.52x for field-moist samples.

Discussion

Farming systems comparisons offer many challenges, even when they are located on adjacent fields that presumably are similar in their soils. For the bulk density comparison, we took soil samples from an area centered on each row. Therefore, a major part of the difference can probably be explained by the use of ridge tillage in the alternative system. The ridges are formed by a cultivator, which pushes and lifts the soil into a loose ridge. Although the data are limited, the difference in soil water content suggests higher retention in the ALT-CORN field, since the two fields received similar amounts of rainfall before sampling.

Water stability of soil aggregates from CONV-SOY was significantly lower than aggregates from ALT-SOY when measured by either wet sieving or turbidimetric techniques (Table 3). The aggregates from the CONV-SOY field also were wetter at sampling and were lower in clay, higher in sand, and lower in total carbon content than

Table 3. Means and t-test levels of significance for Clarion loam sampled in spring 1991 from conventional (Baker) and alternative (Thompson) fields.

Field	Field-Moist Wet Aggregate Stability (FM-WAS)		Carbon	Clay	Silt	Sand	Bulk Density	Gravimetric Water Content
	Turbidity log (%T)[1]	Wet Sieve (%)	(g/kg)	(%)	(%)	(%)	(Mg/m^3)	(%)
CONV-CORN	1.66	50.5	16	15.6	25.4	59.2	1.42	13.9
ALT-CORN	1.72	62.8	22	17.0	30.9	52.1	1.17	18.1
	NS	*	**	NS	**	**	**	**
CONV-SOY	1.24	30.8	15	15.2	26.4	58.4	1.48	17.9
ALT-SOY	1.90	81.6	23	17.0	29.5	53.5	1.36	16.9
	**	**	**	**	**	**	NS	NS

[1] log (%T) is $\log_{10}$ of transmittance, which is the turbidimetric measure of aggregate stability.

Table 4. Simple correlation coefficients for the combined data sets from conventional and alternative fields sampled in spring 1991.

	FM-WAS[1]	Carbon	Clay	Silt	Sand	Bulk Density	Water Content
log(%T)[1]	0.91 ***	0.60 **	0.42 *	0.36 NS	-0.42 *	-0.32 NS	-0.22 NS
FM-WAS		0.76 ***	0.57 **	0.54 **	-0.62 **	-0.39 NS	-0.01 NS
Carbon			0.52 **	0.70 ***	-0.72 ***	-0.51 *	0.15 NS
Clay				0.59 **	-0.80 ***	-0.27 NS	0.38 NS
Silt					-0.95 ***	-0.44 *	0.50 *
Sand						0.44 *	-0.52 **
Bulk Density							-0.25 NS

[1] log (%T) and FM-WAS as defined in Table 3.

those from the ALT-SOY field. All these factors tend to reduce aggregate stability.

From these studies, we cannot identify what aspects of the alternative farming system were responsible for the differences in water stability of soil aggregates. Differences in soil water retention, organic matter content, soil texture, or a combination of these and other properties may be involved. Differences in soil erosion may cause soil textural differences over time, because erosion and deposition processes often increase sand content, and correspondingly decrease clay and silt content (Foster et al. 1985). However, our study cannot confirm this conjecture. Weill et al. (1988) found larger and more water stable soil aggregates when manure was applied to continuous corn fields. Application of animal manure and municipal sludge during three years of each 5 year rotation may be the primary factor causing differences between the two farming systems. Also, it presumably is beneficial to include oat and hay crops in the rotation. To determine the exact mechanisms and causes of the farming system differences, additional studies focusing on soil aggregation processes within these soils will be needed.

Despite the limitations of the present study, the alternative practices appear to have created a soil structure that is superior to that of the conventional system. The higher soil carbon, higher aggregate stability, and lower bulk density lead to higher rainfall infiltration (Logsdon et al., 1993) and higher soil water content in the alternative farming system, and also may decrease erosion.

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UPCOMING EVENTS

May is *American Wetlands Month*; questions, offers to help, and requests for materials should be directed to Jodi Sproul, Terrene Institute, 1717 K St., NW, #801, Washington, D.C. 20006; (202)833-8317.

May 17-June 11, *Sustainable Agriculture Production Systems in Developing Countries*, and **June 14-23,** *Sustainable Agriculture Study Tour*, courses sponsored by the International Center of Agricultural and Resource Development, will be held at Colorado State University; contact: ICARD, B302 Clark Building, CSU, Fort Collins, CO 80523; (303)491-5865.

May 29-31, *Naturopathic Herbal Medicine: Herbal Healing Wisdom for the Future*, the Gaia Herb Symposium, 1993, will be held in Ashland, MA; contact 1993 Gaia Herb Symposium, 62 Old Littleton Road, Harvard, MA 01451.

June 2-5, *Agricultural Biotechnology: A Public Conversation about Risk*, the fifth annual meeting of the National Agricultural Biotechnology Council, will be held in West Lafayette, IN; contact NABC, 159 Biotechnology Building, Cornell University, Ithaca, NY 14853-2703.

Farm Profiles Invited

For its new department on alternative agriculture profiles, the *AJAA* welcomes short articles describing farmers who have adopted interesting alternative practices. The articles should include five elements: a brief description of the farm; the problems that made the farmer look for an alternative approach and the reasons why the alternative seemed plausible; a summary of the basic principles behind the alternative (possibly in a sidebar if it interrupts the flow of text); a discussion of how well the alternative has worked; and a discussion of the applicability of the alternative for other farms. The length should be 1500 to 2000 words.

Submissions must be accompanied by a release, signed by the farmer, giving permission for this material to be published in the *American Journal of Alternative Agriculture*. Vol. 3, No. 4, of the *AJAA* has a further description of the department (page 188); or query the editor for further information. Send submissions to the Editor, *AJAA*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Letters To The Editor Invited

The *AJAA* welcomes letters, short or long, commenting on articles in this journal or sharing ideas likely to be of interest to other *AJAA* readers. Since our space is limited, we do reserve the right not to publish all letters or, at times, to publish only excerpts from them. To take part in this exchange of ideas, write to: Editor, *AJAA*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Land use options on a semi-arid Alfisol

S.K. Das, Shriniwas Sharma, K.L. Sharma, Neelam Saharan, N.N. Nimbole, and Y.V.R. Reddy

Abstract. *Four land use options—annual cropping, agroforestry, agrihorticulture, and agrosilviculture—were tried on a Land Capability Class IVs Alfisol under rainfed conditions to find a farming system that would be profitable and sustainable. The agrihorticultural system required more cash input but gave a value/cost ratio of 2.16 compared with 1.95 with annual cropping, 1.69 with agroforestry and 1.52 with agrosilviculture. Runoff was 4.9% in the agrihorticultural system, and 10.6% with agroforesty. Economic and soil health considerations led to the conclusion that the agrihorticultural system would be a sustainable land use option for the semi-arid Alfisol. However, other options also are profitable, with value/cost ratios of more than 1.50. Therefore, land users can choose among several systems, depending on their desired production level and their investment capacity.*

Key words: agrihorticulture, agroforestry, agrosilviculture, annual cropping, sustainable land use

Introduction

Considerable progress has been made in increasing land productivity through land use systems other than bush-fallow and shifting cultivation. These include alley cropping (Kang et al., 1981, 1984; Kang and Wilson, 1987; Kessler and Breman, 1991), ley farming (Jaradat, 1990), and agroforestry systems (MacDicken, 1990). Singh et al. (1987) and Singh (1990) have suggested alternative land use systems suitable for rainfed lands of India. However, these studies have advocated alternative land use systems irrespective of land capability. We lack information on the productivity of various components of farming systems under different land capability classes. Such information is very important for efficient use of land resources for sustained productivity. It is necessary to optimize the use of land by putting it to the best use that is both consistent with its capability and justified by economic returns.

Different land use options, such as agroforestry, agrihorticulture, agrosilviculture and silvipasture, could increase productivity of the component crops, which vary in economics and productivity. Furthermore, the components might be sustainable because they improve soil fertility, reduce soil erosion and runoff, or increase economic returns. This study was conducted under rainfed conditions to evaluate the performance of selected alternative land use systems on a degraded (Class-IVs) Alfisol.

Materials and Methods

Farming systems

We studied four farming systems:

Site I. Annual cropping. Rotation of blackgram (*Vigna mungo* [L.] Hepper) with grain sorghum (*Sorghum bicolor* [L.] Moench). Under the experimental conditions only one rainfed crop could be raised in a year. However, we could raise horsegram (*Macrotyloma uniflorum* [Lam] Versc) as a second crop after harvest of sorghum in 1990, when rain occurred in late October.

Site II. Agroforestry system. In this system trees were planted at the required spacing, and the land between the tree rows was used to grow food grains. Blackgram, grain sorghum, and horsegram were raised in the alleys of *Acacia auriculiformis*, planted in 1985 in a 4-m × 4-m geometry. The tree saplings were planted on the contour. The layout of the system is shown in Fig. 1. During 1990, trees were trained to remove the branches around the trunk to a height of 2.0 m above the soil surface.

Site III. Agrihorticultural system. In this system, fruit trees were planted in a definite pattern and the interspaces were used to grow food grains. Blackgram, grain sorghum, and horsegram were raised in the alleys of guava (*Psidium guajava* L.) fruit trees planted in 1985 in a 4-m × 4-m geometry. The tree saplings were planted on the contour. Fruit trees were trained in 1990 at a height of 0.75 m. The layout was similar to that of the agroforestry system except that *A. auriculiformis* was replaced by guava.

Site IV. Agrosilvicultural system. In this system, the saplings of leucaena (*Leucaena leucocephala* Lam) were planted in hedge rows, and grain crops were raised in the interspaces. Blackgram, grain sorghum, and horsegram were planted in the alleys of leucaena planted in 1985 in a 4-m × 4-m geometry. The leucaena saplings were planted on the contour. Leucaena was managed as hedgerows by lopping at 0.5 m above ground level at the start of each planting season. Lopping also was done during each cropping season (June-September) and each off-season (October-May). The loppings were removed from the field. The layout was similar to that of the agroforestry system.

S.K. Das is Principal Soil Scientist (Soil Chemistry/Fertility), S. Sharma is Principal Scientist (Soil and Water Conservation), K.L. Sharma is Scientist (Soil Chemistry/Fertility), N. Saharan is Scientist (Agricultural Chemistry), N.N. Nimbole is Scientist Selection Grade (Agronomy), and Y.V.R. Reddy is Principal Scientist (Agricultural Economics), Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad - 500 639, Andhra Pradesh, India.

Annual crops were planted each year with adequate rains in June. A second crop of horsegram was planted in October 1990, after harvest of blackgram, in all four land use systems. Sorghum received 40 and 13 kg/ha N and P, respectively. Planting and basal fertilization was done with a tractor-drawn 3-tine seed-and-fertilizer drill. Di-ammonium phosphate was used for basal fertilization to supply N and P at 11 and 13 kg/ha, respectively. The remaining 29 kg/ha N was top dressed as urea 30 to 35 days after planting by opening a furrow in the middle of two rows with a bullock-drawn country plow. The furrows were covered with soil after urea application. Blackgram received N and P at 11 and 13 kg/ha, respectively, as diammonium phosphate at seeding. Horsegram was raised in 1990 after blackgram without any fertilizer application. At harvest, we recorded grain and stover yields of the crops, as well as the yield of native grass growing as a weed in the alleys along with the crops during 1989 and 1990. Guava started bearing fruit in 1988, and the yields were measured at maturity each year. We measured tree height at the end of the experimental seasons in 1989, 1990 and 1991. Canopy size of the trees was recorded by measuring area of shade in mid-day (between 1130-1230 hours). We measured fire wood from *A. auriculiformis* and guava obtained from training the trees in 1990, and recorded the amount of loppings of leucaena in all years.

Experimental sites

The experiment was conducted at Hayathnagar Research Farm of the Central Research Institute for Dryland Agriculture on a typic Haplustalf at 78°36′E longitude and 17°18′N latitude, at an altitude of 509 m. The average annual rainfall is 760 mm, and the location is a semi-arid environment. The weekly distribution of rainfall each year from 1988 to 1991 is shown in Fig. 2. Each farming system was put in a separate and hydrologically independent block. This was done by identifying the ridge lines through a contour survey. The ridge lines were strengthened by earthen bunding. The experimental area in each block varied from 0.14 to 0.21 ha (Table 1). Effective soil depth ranged from 12.7-20.0 cm. Disintegrated rocks predominated below this soil depth. Based on tex-

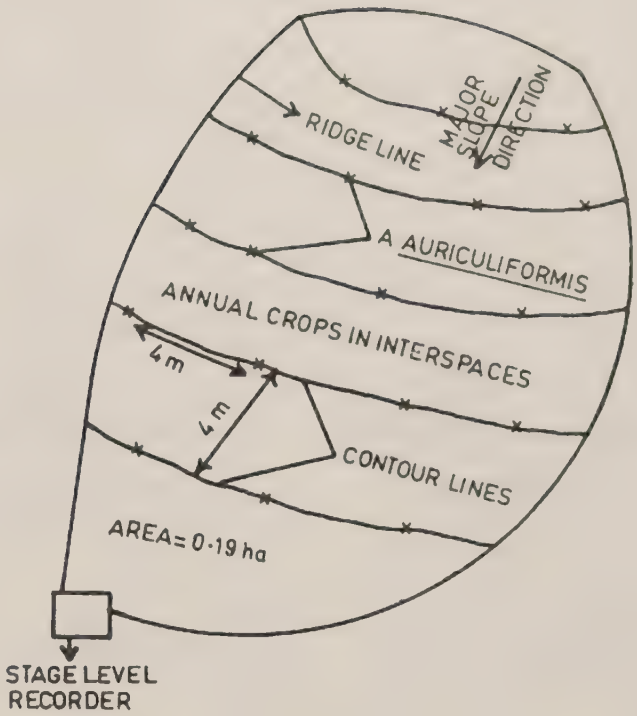

Figure 1. Layout of agroforestry system.

Table 1. Characteristics of the experimental sites.

Characteristic		Site I	Site II	Site III	Site IV
Sand (%)	0-15 cm	90.0	82.8	88.0	90.6
	15-30 cm	88.6	78.8	88.0	84.6
Silt (%)	0-15 cm	2.0	2.6	2.0	6.0
	15-30 cm	4.0	2.6	4.0	4.0
Clay (%)	0-15 cm	8.0	14.6	10.0	3.4
	15-30 cm	7.4	18.6	8.0	11.4
Texture	0-15 cm	sand	sandy loam	loamy sand	sand
	15-30 cm	sand	sandy loam	loamy sand	sand
Effective soil depth (cm)		20.0	17.0	12.7	14.2
Average land slope (%)		1.2	1.5	2.3	1.0
Experimental area (ha)		0.15	0.19	0.21	0.14
Land capability class (LCC)		IVs	IVs	IVs	IVs

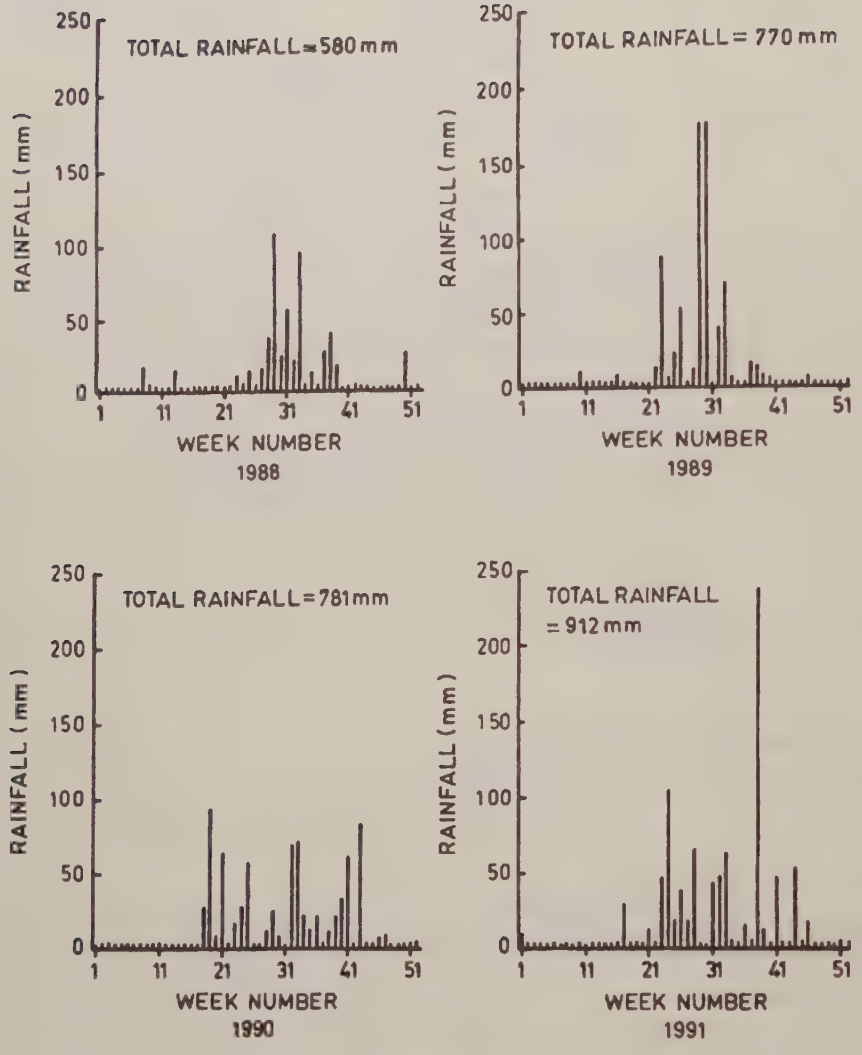

Figure 2. Weekly rainfall distribution during the experimental years.

ture, soil depth and slope, the sites were classified as Land Capability Class-IVs (Klingebiel and Montgomery, 1961).

Runoff

The areas under agroforestry, agrihorticulture and agrosilviculture were demarcated with ridge lines. Automatic stage-level recorders were installed at the lower outlet point. Runoff was recorded at sites II, III and IV for each rainfall that caused runoff, and summed at the end of the cropping season.

Economic analysis

We did an economic analysis of the farming systems as described by Reddy and Korwar (1985). The assumed life span of the tree components was based on the utility of the species. *Acacia auriculiformis* would be felled after 10 years of growth. A guava plantation can produce profitable fruit yield for 15 years. Wood production was assumed to be 500 and 300 t/ha over the life of *A. auriculiformis* and guava, respectively.

Results and Discussion

Biological harvests

The yields obtained from each component of the farming systems are presented in Table 2. Grain yield of blackgram and sorghum varied with farming system and season. Blackgram yield was higher (1.02 t/ha) in the annual cropping system in 1988, because there was almost no moisture stress during the growing season (Fig.2). Because the crop experienced prolonged moisture stress in 1990 from the fourth week of June to the middle of July and again at the end of July, the grain yield was low in the annual (0.65 t/ha) and other cropping systems. Sorghum grain yield was adversely affected in 1989 and 1991, primarily because dry spells prevailed during the reproductive stage of crop growth (end of August to middle of September). Yields of both crops decreased in all three alternative land use systems compared with annual cropping because of competition for moisture (Singh et al., 1989). However, the yield of the second horsegram crop was similar in the sole crop and agrosilvicultural systems in 1990. This might have been due to reduced competition for light (leucaena was lopped at horsegram seeding) and moisture (Kang et al., 1981). It also is likely that under drought conditions, the activity of leucaena roots in surface soil would be low. In the agroforestry and agrihorticultural systems, the shading effect could significantly reduce yield of horsegram (Verinumbe and Okali, 1985).

The reduction in the yield of blackgram was more than that of sorghum with alleys (Table 3). Comparatively, the reduction in yield of blackgram was more in agroforestry than in the agrihorticulture and agrosilviculture systems. Only 10 to 18% of sole crop yield of blackgram was obtained in the agroforestry system. In other cases it varied from 22 to 32%. In contrast, sorghum yield in these systems was 33 to 100% of sole crop yield. Sorghum yield in

Table 2. Yields recorded with different land use options in different years.

Year	Crop	Yield (t/ha)					
		Grain	Dry/fresh stover	Dry grass	Firewood	Fruit	Fresh fodder
				Annual cropping			
1988	Blackgram	1.02	--	--	--	--	--
1989	Sorghum	1.22	3.00	0.97	--	--	--
1990	Blackgram	0.65	1.66	--	--	--	--
	Horsegram	0.88	1.44	--	--	--	--
1991	Sorghum	1.71	8.24[1]	--	--	--	--
				Agroforestry			
1988	Blackgram	0.19	--	--	--	--	--
1989	Sorghum	0.64	1.44	2.17	--	--	--
1990	Blackgram	0.06	0.18	2.18	3.62	--	--
	Horsegram	0.20	0.32	--	--	--	--
1991	Sorghum	0.62	2.46[1]	--	--	--	--
				Agrihorticulture			
1988	Blackgram	0.23	--	--	--	0.62	--
1989	Sorghum	1.22	3.49	0.47	--	1.08	--
1990	Blackgram	0.17	0.30	0.97	0.28	0.56	--
	Horsegram	0.44	0.75	--	--	--	--
1991	Sorghum	0.94	3.75[1]	--	--	4.12	--
				Agrosilviculture			
1988	Blackgram	0.22	--	--	--	--	16.4
1989	Sorghum	0.40	1.67	2.07	--	--	24.2
1990	Blackgram	0.21	0.50	0.50	--	--	3.8
	Horsegram	0.90	1.49	--	--	--	--
1991	Sorghum	0.60	2.46[1]	--	--	--	10.6

[1] Fresh fodder yield.

Table 3. Relative grain yield under alternate land use systems in different years.

System	% of Sole Crop Yield			
	Blackgram		Sorghum	
	1988	1990	1989	1991
Agroforestry	18	10	53	36
Agrihorticulture	23	26	100	55
Agrosilviculture	22	32	33	35

the alleys was highest (55 to 100% of sole crop yield) in the agrihorticultural system.

Fruit yield from guava ranged from 0.56 to 4.12 t/ha. Yield varied with rainfall and increased with age of the trees. With favorable amount and distribution of rain, guava gave a fruit yield of 4.12 t/ha in 1991. Poor yield of fruit (0.56 t/ha) in 1990 was due to inadequate rains from the first week of July to the first week of August, which coincided with the flowering stage. Consequently, there was flower drop, and the fruit setting was low. Fodder yield from the loppings of leucaena ranged from 3.8 to 24.2 t/ha, increasing with rainfall and age of the stumps. The yield of 10.6 t/ha in 1991 is the combined yield of two harvests, one just before seeding of sorghum and another in the middle of the growing season. In other years, leucaena also was harvested in the off-season (October-May). The amount of fire wood collected during 1990 from training of trees was 3.62 and 0.28 t/ha for *A. auriculiformis* and guava, respectively.

Runoff

Runoff and runoff volume, which depend more on the intensity of rain than on the total amount of rainfall (Chow, 1964), varied among years (Table 4). Runoff was substantially lower with the agrihorticultural (4.9%) and agrosilvicul-

Table 4. Rainfall causing runoff, and runoff under different farming systems during the crop season.

	System		
	Agroforestry	Agrihorticulture	Agrosilviculture
1988 (Rainfall = 455 mm)			
Runoff volume (mm)	91.0	19.0	35.6
Runoff (%)	19.9	4.2	7.8
1989 (Rainfall = 666 mm)			
Runoff volume (mm)	19.6	13.6	17.0
Runoff (%)	2.9	2.0	2.5
1990 (Rainfall = 172 mm)			
Runoff volume (mm)	5.3	5.2	2.9
Runoff (%)	3.0	3.0	1.7
1991 (Rainfall = 631 mm)			
Runoff volume (mm)	106.2	64.8	20.9
Runoff (%)	16.8	10.3	3.3
Mean of four years			
Runoff volume (mm)	55.5	25.6	19.1
Runoff (%)	10.6	4.9	3.8

Table 5. Tree height (m) after each crop season.

Tree	Year		
	1989	1990	1991
A. auriculiformis	3.97	5.92	6.40
Guava	1.77	2.22	2.68

Table 6. Canopy coverage (m) after the 1991 crop season.

Tree	Direction	
	East-West	North-South
A. auriculiformis	3.50	3.22
Guava	2.95	3.15

tural (3.8%) systems than with the agroforestry (10.6%) system. Earlier studies under similar agroclimatic conditions showed that runoff with arable crops can vary from 9 to 14% and that soil loss decreases with decreasing runoff (Sharma et al., 1988). Less runoff in the agrihorticultural system, despite its greater land slope (2.3%), might be due to the bushiness of the fruit trees (Wiersum, 1984) compared with the tall *A. auriculiformis* of the agroforestry system, for which the erosivity of rain drops increased (Wiersum, 1985). The hedgerow in the agrosilvicultural system significantly reduced runoff, as postulated by Young (1989).

Tree growth

After six years' growth, *A. auriculiformis* attained a height of 6.40 m, compared with 2.68 m for guava (Table 5). Low rainfall in 1990 might have restricted the tree growth after 1990. Canopy coverage in *A. auriculiformis* was 3.50 and 3.22 m east-west and north-south, respectively (Table 6), while coverage for guava was 2.95 m and 3.15 m. These data show that the canopy was nearly closed in a 4-m × 4-m stand.

Economic evaluation

The economic evaluation of the land use options revealed that costs were highest in the agrihorticultural system (Table 7). However, that system also was most profitable, with a value/cost ratio of 2.16. The annual cropping system ranked second among the four systems based on profit and value/cost ratio, while the agroforestry and agrosilvicultural systems were ranked third and fourth, respectively.

Conclusions

Determination of an appropriate land use option has relevance to the efficient use of soil and water resources (Abrol, 1991; Khanna, 1991; Swindale, 1991). Growing

Table 7. Economic evaluation of different land use systems.

System	Life span (yrs)	Cost (Rs/ha)[1]	Profit (Rs/ha)	Value/cost ratio	Ranking based on profit
Annual cropping	1	2780	2650	1.95	2
Agroforestry	10	2900	2000	1.69	3
Agrihorticulture	15	5150	5950	2.16	1
Agrosilviculture	6	2800	1500	1.52	4

[1] 1 US $ = Rs. 30.0, approx.

arable crops on marginal lands further degrades the land because of soil loss through runoff. Earlier studies have shown that silvipastoral systems are profitable for degraded Alfisols (Saharan et al., 1989). As greater food production demands are placed on land because of the socio-economic conditions of dryland farmers (Singh, 1989), it is necessary to evaluate food crop farming systems that maintain or increase both crop and soil productivity.

An agrihorticultural system with broadleaf fruit trees enhances soil conservation and profitability, although the required investment also is higher. Other land use options have similar investment requirements. This study has identified a sustainable land use system for a semiarid dryland Alfisol (LCC-IVs), and should help land users choose a land use appropriate to their socio-economic conditions.

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Native American Tribe Revitalizes Itself with Sustainable Farming

A small tribe of Santa Ana Native Americans in New Mexico has revitalized itself by returning to sustainable farming and, specifically, growing organic blue corn that is used in a sophisticated line of internationally marketed cosmetics, according to *The New York Times*.

Faced with a declining agriculture, the tribe adopted a plan in the mid-1980s to revive its farming through organic and environmentally sound agriculture. The tribe recently received a $20,000 prize for enterprise from The Ford Foundation, which found the Santa Ana Indians had demonstrated "an extraordinary, integrated communal vision." According to tribal administrators, the tribe's next venture will be a retail shop to sell nonchemical fertilizers.

COMMENTARY

Can agricultural colleges meet the needs of sustainable agriculture?

William B. Lacy

Abstract. *As concern about the long-term viability of our food and fiber system has grown, many agricultural research administrators, prominent scientists and policymakers have focused increasing attention on the important research and educational needs in sustainable agriculture. Colleges of agriculture should be important in meeting the challenges of sustainable agriculture; a central question is whether they are adequate for the task. This paper highlights several individual and institutional constraints that limit the ability of these colleges to address the needs: 1) assumptions and biases regarding the relationship between humans and nature, and the concept of progress; 2) the demographic characteristics, education, and experience of research scientists; 3) the specialized departmental organization of research institutions; 4) imbalances among analyses on the molecular, cell, organism and ecosystem levels; 5) emphasis on farm level analysis and technology development; 6) new agricultural biotechnologies that may overemphasize short-term, narrow technical considerations and proprietary products; 7) compartmentalization of education by discipline, and the limited informal and field experiences for students; 8) the background and education of current Extension Service agents; 9) the emphasis on economic effects in research impact assessments, to the neglect of environmental effects and social consequences for farmers, rural communities and society at large; 10) limited capability for comprehensive public policy analysis.*

Despite these limitations, new research agendas and college programs are effectively addressing many needs of sustainable agriculture systems. To be more successful, these efforts must be broad-based and sensitive to a wide range of issues, and must include all participants in the system.

Key words: agricultural education, Extension, policy analysis, biotechnology

Introduction

Few agricultural issues in recent years have aroused greater public concern than the unanticipated and undesirable effects of today's agriculture on natural resources, environmental quality, and the health of humans and animals. Conventional agriculture, with its resource consuming practices and heavy use of fertilizers, pesticides, and other inputs purchased off-farm, has been remarkably effective in making the United States agricultural system among the most productive in the world. However, this impressive productivity has come with substantial costs. There is broad concern about depletion of our natural resource base, exemplified by loss of biological diversity, native prairies, wetlands, and forests, and about depletion of fossil fuels and water supplies. Other specific concerns include persistent soil erosion, groundwater contamination, loss of fish and wildlife, and growing pest resistance to pesticides. Agriculture has been identified as the largest non-point source of surface water pollution. Moreover, some people believe that our food is unsafe, or at least potentially unsafe, because of pesticide residues, antibiotics, hormones, and other additives. Additional concerns have arisen regarding health risks that farm chemicals pose for applicators, harvesters, irrigators, field hands, farmers and their families, and rural communities. Finally, there is uncertainty about the future profitability of farming and the viability of rural communities.

Consequently, during the 1980s and into the 1990s, support has grown among farmers and others for an agriculture that will remain productive and profitable, conserve resources, protect the environment, and enhance public health and safety. A few years ago these goals were embraced by only a small group of people. Today, the sustainability concept has entered mainstream thinking and has become a major item on the agricultural policy agenda. Several agricultural research administrators, prominent scientists, and policymakers have assigned a high priority to sustainability in American agricultural research, and have begun substantial research and education programs in the area.

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William B. Lacy is Assistant Dean for Research and Professor of Rural Sociology, College of Agricultural Sciences, The Pennsylvania State University, University Park, PA 16802.

What is Sustainable Agriculture?

Sustainable agriculture is a complex concept that refers to an interconnected framework of technologies, practices, and systems being developed in response to problems currently facing agriculture and our food system. A recent definition in the Food, Agriculture, Conservation and Trade Act of 1990 (Title XVI, Subtitle A, Section 1603, quoted in Bird, 1992, p. 3) captures part of this complexity:

> Sustainable agriculture is an integrated system of plant and animal production practices having a site-specific application that will, over the long-term, satisfy human food and fiber needs; enhance environmental quality and the natural resource base upon which the agricultural economy depends; make the most efficient use of nonrenewable resources and on-farm/ranch resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm/ranch operations; and enhance the quality of life for farmers and ranchers, and for society as a whole.

The system must be economically sound, socially acceptable, and environmentally compatible. The challenge of sustainable agriculture research and education programs is to develop systems that meet these three interconnected goals. Because of the complexity suggested by this model, a key component in achieving sustainability is information management and decision-making. A sustainable approach requires producers to substitute management, scientific information, and on-farm resources for the purchased inputs on which their farming enterprises currently depend.

Perhaps the most comprehensive definition of sustainable agriculture was proposed recently by Allen et al. (1991, p. 37): "A sustainable agriculture is one that equitably balances concerns of environmental soundness, economic viability and social justice among all sectors of society." This definition moves beyond short-term microeconomic profitability at the farm level to consider the entire agricultural system, not only through time, but worldwide, with priority given to broad-based equity considerations. The focus on equity requires that decisions are truly democratic and that costs and benefits not only are identified, but also are distributed fairly among all sectors of society.

What are the Research and Education Needs of a Sustainable System?

According to John Pesek (quoted in Cook, 1991, p. 32), an agronomist from Iowa State University who chaired the National Research Council's *Alternative Agriculture* report (1989):

> Alternative farming practices . . . are far more than conventional agriculture with lower inputs of fertilizer and pesticides. They are an array of options that emphasize management and take advantage of biological relationships that occur on the farm. The objective is to enhance and sustain rather than to reduce and simplify these relationships; to make them relevant to the production system rather than irrelevant; not to mask them with excesses.

Therefore, diverse research and educational programs are necessary, and complex biological and social relationships must be sustained and enhanced. The research agenda to address these relationships should have several elements: experimental and exploratory component research that improves our understanding of natural and managed systems; integrated projects that examine whole farms and ranches, and natural systems; impact assessments that examine the economic, environmental and social consequences of sustainable agriculture practices at the local, regional and national levels; decision support systems and artificial intelligence projects that address the information needs and complexities of dealing with whole farm systems; and policy research that analyzes policies conducive to sustainability (Bird, 1992). The educational needs include both strong disciplinary and interdisciplinary education, formal classroom and field experiences for students at both the undergraduate and graduate level, programs to educate the educators, whole farm or ranch site demonstration projects, and conferences and workshops. Furthermore, research and extension programs supporting sustainable agriculture systems require an integrated approach that entails interdisciplinary cooperation, functional integration of research and extension, and inter-organizational collaboration among institutions and agencies.

Choosing research priorities, and the research itself, must involve the opinions of a broad cross-section of farmers, farm organizations, suppliers and processors, scientists and extension faculty, environmental and consumer organizations, and government agencies and policymakers. Moreover, the new and exciting research paradigms and programs emerging in sustainable agriculture must avoid becoming rigid and dogmatic. Finally, all participants must remain vigilant to ensure that research and education are always of the highest quality (Harwood, 1990).

Constraints on Agricultural Colleges

Given this broad research and educational agenda for sustainable agriculture, an important question logically follows: Are agricultural colleges adequate to meet these needs? The short answer to this question is that increasingly they are, but only selectively. The colleges have extensive research and educational capabilities to address the sustainable agriculture agenda, but they also have constraints that limit their ability to meet these needs. The growth of sustainable agriculture research culminated two tumultuous decades of political conflict over the goals and agenda of agricultural research. Beginning with Jim Hightower's book *Hard Tomatoes, Hard Times* (1973), and continuing with several additional critiques that examined environmental impacts, the quality of the research, and issues of social justice and social equity, the public research system and our colleges of agriculture have been put on the defensive (Busch and Lacy, 1983).

Sustainable agriculture research is an attractive response to the criticisms of public agricultural research and the emergence of farmer opposition to the land-grant system. Several constraints on individuals and institutions limit agricultural colleges' abil-

ity to respond to the needs and opportunities of a sustainable agriculture. The following discussion is designed to highlight several issues that should be addressed for future agricultural research and education to support sustainable agriculture effectively.

Assumptions and biases. Several assumptions and biases in science and society may inhibit agricultural colleges from developing sustainable agriculture concepts and practices. First is the belief that humans are separate from nature, with nature something to be controlled, domesticated, and dominated. This view results in a failure to understand how human societies fit into and depend on larger natural systems. Second, progress often is characterized as a technological imperative, and is viewed exclusively as the increased application of science and technology (Dahlberg, 1987). This means that evaluation of progress is limited to such measures as output, utility and efficiency, instead of encompassing the entire context in which human beings live, including all the economic, social and ethical dimensions. Finally, there is a tendency to neglect the needs of others who are separated from us either by physical space, socioeconomic status or by time (future generations). This can result in insensitivity to the equity issues embedded in sustainable agriculture.

Researchers' backgrounds. Agricultural colleges' research priorities are shaped by researchers' backgrounds and training. Although scientists usually are considered objective, research agendas are influenced by scientists' education, experiences, and political, economic and ethical perceptions. U.S. agricultural researchers predominantly are white males, educated in particular applied biological sciences at a few prestigious universities with agricultural colleges. Just a dozen land-grant institutions have educated nearly three-fifths of public sector agricultural scientists (Busch and Lacy, 1983). Underrepresented in this system are scientists from a wider array of institutional and disciplinary backgrounds, and female and ethnic minority scientists. The broad experiences and innovative ideas required to make research programs responsive to a sustainable agriculture agenda may be lacking. This may lead to a narrower and more traditional set of perceptions and research programs.

Institutional structure. The generally hierarchical and departmentally specialized structure of research institutions also shape the research programs. The process of conducting research, generating new knowledge, and disseminating results often is fragmented into narrow disciplinary and commodity subspecialties. Agricultural scientists tend to maintain sharp disciplinary divisions in their educational background, research orientation, criteria for research problem choice, communication patterns with scientific colleagues, and publication activities (Busch and Lacy, 1983). The reward system places great emphasis on prestigious disciplinary journals, and inadequately recognizes long-term research or unusual and innovative research that is not publishable in disciplinary journals. Although there is no inherent conflict between disciplinary problems and problems of concern to society, we do not have adequate mechanisms to ensure that disciplinary objectives will be consistent with societal needs. In focusing on problems that are deemed important by a particular discipline, scientists ignore problems that are outside their competence, or regard them as unimportant. In a study of U.S. public sector agricultural scientists in the early 1980s (Busch and Lacy, 1983), researchers were asked to rate the importance of eleven broad goals for agricultural research identified by the U.S. Department of Agriculture. They saw a strong relationship between the goals to which their research contributed and the goals perceived as intrinsically important. Conversely, they tended to undervalue the importance of activities to which they directly contributed little, such as nutrition and health, the quality of life in rural America, community development, and Third World development. Consequently, the research system has been highly effective in conducting disciplinary component research and in developing methods for increasing commodity production. However, it has been less effective in analyzing complex biological and social systems and anticipating and resolving environmental and socioeconomic problems. We need to find ways, both through education and through reforming the organization and structure of research, to increase agricultural scientists' understanding of social issues, economists' understanding of ecological issues, and sociologists' understanding of practical farming issues (Allen and Van Dusen, 1990).

Disciplinary imbalances. An appropriate balance must be maintained among analyses on the molecular, cellular, whole plant, and ecosystem level. Plant-level analysis has been a traditional strength in colleges of agriculture, which once devoted significant resources to plant breeding and germplasm research. During the mid to late 1980s, however, cellular and molecular biology programs tripled within colleges of agriculture, while the number of plant breeders was reduced by approximately one-third (Busch et al., 1991). Moreover, despite the growing national and international interest in ecology and systems level analysis, this important area has grown little at colleges of agriculture. The current and future composition and emphasis within the research community may make it difficult to conduct the integrated holistic research needed as part of the sustainable agriculture agenda.

Farm-level and technological emphasis. Agricultural research in colleges of agriculture has focused primarily on the farm level and on developing equipment, chemicals, hybrid seeds and other technologies suitable for an agriculture that depends heavily on synthetic chemicals, fossil fuels, irrigation, and intensive mechanization. Less emphasis has been placed on discovering or developing alternative technologies, practices, and processes, or on effectively integrating new discoveries into a sustainable system. Such research is essential to sustainable agriculture, but it must be part of a broader context that examines sustainability within biological and ecological systems (for example, watersheds) and within political and social systems, from the state to the international level. Moreover, farm production is only one essential component of the food and fiber system. Other sectors that are equally important include agricultural inputs, food processing, distribution, marketing, retailing, and waste management. These have been examined much less thoroughly. Addressing all components of the food and fiber system will require a wider range of expertise and a research agenda that includes interdisciplinary,

long-term, whole systems analyses (Allen and Van Dusen, 1990).

Molecular biology. The new and exciting developments in molecular biology and genetic engineering may be important tools in developing a more sustainable agriculture: "Biotechnology and genetic engineering hold enormous beneficial possibilities for agriculture, the environment and food production worldwide" (Doyle, 1985, p. 384). Biotechnology could offer new opportunities to tailor crops to specific needs, reduce the use of purchased inputs, improve nutritional quality, and reduce environmental problems associated with agriculture. Alternatively, they could increase dependence on the input and output sectors of the agribusiness community, contributing to further concentration in the chemical, fertilizer, seed, and processing industries. Also, they could be used to mask environmental problems by developing such products as trees resistant to acid rain, honey bees resistant to insecticides, and salt tolerant crops (Lacy et al., 1988). Traditionally, research funded by agribusiness has encouraged short-term, economics-based agendas emphasizing technology development rather than broader social impact analyses. It has focused on maximizing production, minimizing production costs and consumer prices, and maximizing the market share of certain agricultural commodities. In proposing new technological solutions through biotechnology, it will be important to consider how these solutions and products will be used, how they will contribute to sustainable agriculture, who will benefit from their development, and who will incur the costs (Lacy et al., 1992).

Educational reforms. Education has been compartmentalized by discipline, and often is limited to formal classroom experiences. Colleges of agriculture need to continue exploring ways to integrate formal and informal educational experiences and to expose students more effectively to field experiences. Traditionally they have offered more opportunities for such integration and field experiences than most other colleges and universities, through such activities as clubs, intern programs, and farm and forest fieldwork. However, with the recent emphasis on laboratory sciences and reductions in field operations, these opportunities have become less available. Cooperating with local farmers and combining local, informal knowledge with scientific information can effectively promote integration of formal and informal educational and field experiences.

Needed changes in Extension. The Extension Service has been an effective way to deliver information and to educate producers. Although current agents are knowledgeable about conventional farming practices, to meet the needs of sustainable agriculture they will need to become informed about new practices and new perspectives. Educating the educators will be important to insure that the colleges play a significant role. In addition, the extension model has been that researchers provide information to extension agents, who convey it to producers. For sustainable agriculture to be developed effectively, the researcher, the extension worker, and the producer must be viewed as team members who will learn from each other (Schaller, 1992).

Impact assessment. Research at agricultural colleges on sustainable agriculture and on the impact of agricultural technology has increased in both quality and quantity in the past decade. However, this research generally has not received adequate funding, and has lacked methodological sophistication. Also, it has emphasized the economic performance of the agricultural sector, rather than the impacts of technology and alternative practices on the environment, or their social consequences for farmers, rural communities, and society at large. Highly efficient and sustainable farms can increase exports of farm products while storefronts in rural towns are boarded up and thriving rural communities become an image of the past. Traditional performance indicators such as yields, production, farm income, food prices, and exports cover only some of the important interconnecting goals of sustainable agriculture. A recent report (Schaller, 1991) suggests that the research community identify indicators that will encompass environmental concerns and social impacts. It further recommends that social scientists assume much of the responsibility for developing these indicators.

Public policy analysis. Public policies are critical for achieving sustainable agriculture's goals because they create incentives or disincentives for individuals, institutions and political entities to take a wide range of actions. Policies relevant to sustainable agriculture include taxes, commodity programs, water subsidies, trade policy, credit allocations, environmental regulations, research and education programs, food safety and market regulations, and international aid programs (Allen and Van Dusen, 1990). Although agricultural colleges have addressed some of these issues in detail, they generally do not cover all of them adequately, nor do they assess them as an integrated system. The colleges also need to strengthen their capability to do research on the types of political bodies and decision-making procedures conducive to sustainability at the local, state, national and international levels.

Current College Agendas

Despite the limitations of colleges of agriculture, in the eyes of the public they remain a highly credible source of information. In recent surveys conducted at Penn State's Ag Progress Days, the Pennsylvania Farm Show, and the conference of the Pennsylvania Association for Sustainable Agriculture at Penn State, respondents consistently said that university scientists were the most credible source of information about sustainable agriculture practices. A majority also believed the Rodale Research Institute, the Pennsylvania Department of Agriculture, the U.S. Department of Agriculture, and organic farming groups. To a much lesser extent the public believed the statements of environmental groups and the U.S. Environmental Protection Agency. The least credible information source on sustainable practices was the news media (Lacy, unpublished).

There are several reasons the public has confidence in university scientists regarding sustainable agriculture. For many years, colleges of agriculture have engaged in a wide range of research and educational activities that addressed various components of sustainable agriculture. Soil conservation and tillage, crop rotations, green manure management, and integrated pest management (IPM) strategies are examples of important component research in support of sustainable agriculture that should be continued, but integrated into complete systems. For example, it no longer is enough to fragment research and

education efforts into IPM for insects, IPM for diseases, IPM for weeds, and IPM for nematodes, leaving the real integration to farmers. The agenda must be expanded to include more holistic approaches, perhaps developed around the principles of plant health management (Cook, 1991).

In recent years, colleges of agriculture across the country have sought to augment their research and educational programs on sustainable agriculture. One important way has been through the U.S. Department of Agriculture's Sustainable Agriculture Research and Education Program (SARE, formerly LISA). Since its beginning in 1988, this innovative program has funded over a hundred projects. It has tried to respond to a wide range of clients, and has involved farmers, researchers, educators, federal and state administrators and industry representatives on the technical review committees that shape funding decisions. Unfortunately, this initiative is very underfinanced, and hundreds of excellent proposals have gone unfunded. Nonetheless, it remains one of the most promising efforts in the country to promote and stimulate sustainable agriculture research and education.

Colleges of agriculture and land-grant universities also have been active in developing new institutional arrangements and centers for sustainable agriculture. Among the most prominent is the Leopold Center for Sustainable Agriculture at Iowa State University. Established in 1987, it seeks to identify and reduce adverse environmental and socioeconomic impacts of farming practices, develop profitable farming systems that conserve natural resources, and create educational programs with the Cooperative Extension Service. In its first three years, the center funded $2.3 million in research at eleven institutions and non-profit organizations in Iowa on such topics as water quality, crop and livestock management, biological pest control, forestry, energy production and use, soil fertility, and social and economic implications (Leopold Center, 1990). Another successful effort is the Sustainable Agriculture Research and Education Program at the University of California, Davis. Substantial state appropriations have helped to support research, hire staff, and publish an excellent nationally distributed newsletter. At Michigan State University, $3.5 million was recently set aside to establish the Charles Stewart Mott Distinguished Professor in Sustainable Agriculture. This position is responsible for catalyzing a campus-wide program of excellence in sustainable agriculture. The Michigan program is only in its initial stages, however.

For the past several years, the College of Agricultural Sciences at Penn State has been developing a program of research and education on sustainable agriculture. Under USDA's SARE program, Penn State has conducted research on alternative rotations and rotations for low-input agriculture, alternative strategies for small fruit production, and honey bee breeding for mite resistance. Also, through several USDA Water Quality grants, college internal grant funds, and the Chesapeake Bay program, faculty and staff have initiated research projects and educational programs on nutrient management, soil monitoring, nitrate leaching, and water quality. Extensive research has been conducted over the past decade on integrated pest management, biological controls, and expert systems and decision support technology to manage the increased information needs of sustainable pest management systems. Most recently, to provide leadership in this area the College has established the Sustainable Agriculture Research and Education Issues Committee as one of its twelve interdisciplinary research and education committees. This committee of twenty-five research and extension personnel has several functions: to identify and analyze research and educational needs in the sustainable agriculture area; to define appropriate action strategies and recommend mechanisms to implement them; to communicate the needs, strategies and other information regarding these issues to appropriate audiences, such as by sponsoring conferences and seminars; and to interact with foundations and appropriate national, state and local public and private agencies. Finally, the College has recognized the need to build stronger links with various organizations conducting related sustainable agriculture research and education. In 1992 the Penn State/Rodale Center for Sustaining Agriculture and Natural Resources in Urbanizing Environments (SANRUE) was established with support from USDA Cooperative State Research Service, Extension Service, and the Agricultural Research Service. This new center should lead to important collaborative research and educational programs.

Conclusions

The challenge facing today's agricultural colleges is to address effectively the production, environmental, economic, and social dimensions of the food and fiber system through an integrated and holistic approach, and to develop local, regional and global strategies for achieving a sustainable agriculture. Success in meeting this challenge will require the perspectives and involvement of all the participants in the system, including farmers, suppliers, processors, wholesalers, retailers, consumers, policymakers, environmentalists, regulators, researchers, and educators. The task has only just begun. However, as cultural historian Thomas Berry has written, "the human community and the natural community will go into the future as a single sacred community or we will both perish on the way" (quoted in Ebenreck, 1992, p. 5).

Our colleges of agriculture can and should be key actors in meeting the challenge of sustainable agriculture. In that capacity we need to be good learners as well as good teachers and researchers: "Using the metaphor that agriculture is a conversation between humans and nature, perhaps there has been too much talking and not enough listening" (Gardner et al., 1991, p. 90).

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INSTITUTE NEWS

Institute Conference Explores a New Time to Choose for Alternative Ag

Future policy opportunities for alternative agriculture were explored by revisiting the past at the Henry A. Wallace Institute for Alternative Agriculture's 10th annual conference on March 1 entitled, *Alternative Agriculture Policy: A New Time To Choose*. More than 150 people attended. The morning sessions, moderated by Wallace Institute Executive Director Garth Youngberg, "looked back" at two landmark studies requested by U.S. Agriculture Secretary Bob Bergland during the Carter Administration: *A Time to Choose* (1981), a report on the changing structure of American agriculture, and *Report and Recommendations on Organic Farming* (1980).

A Time to Choose has had significant impacts on agriculture, according to Lynn Daft of the consulting firm Abel, Daft & Earley. "It produced forward movement on long-term conservation; tighter farm credit; increased prominence of environmental, food safety, and dietary issues; integration of trade and farm policy; and a reduced role of government." Richard Harwood of Michigan State University discussed the "triumph and tragedy" of the organic farming report, including the difficulties faced by the research team in evaluating "indigenous knowledge" of organic farmers who were "outside the scientific paradigm" at a time when conventional scientific models dominated. Nevertheless, when the report was published, "no firestorm erupted, and some scientists began to see the potential of organic agriculture."

At the time, the reports were "a breath of fresh air for me on the farm," said Iowa farmer Paul Johnson, who served on a panel with Cornelia Flora of Virginia Polytechnic Institute and State University, and Bob Papendick of USDA's Agricultural Research Service, Washington State University. Flora stressed the importance of the organic farming report's use of indigenous knowledge within the context of agricultural policy, community and institutions; according to Papendick, the study found that the motivation for many farmers to turn to organic farming was concern for soil quality, which is "the key to agricultural sustainability."

Wallace Institute Associate Director Neill Schaller moderated the afternoon session of "looking ahead" with Kathleen Merrigan of Massachusetts Institute of Technology and a former key staff member of the Senate Committee on Agriculture, Forestry, and Nutrition, who reviewed the lessons of the 1990 Farm Bill that could help to encourage sustainable agriculture in the future. She cited a need to fill the "knowledge gaps" that occurred during the Farm Bill debate with more science and policy analysis, and to follow through on the legislation once it becomes law. "Many of the programs authorized by the Farm Bill didn't get off the ground" because of lack of funding, she said. Her advice for the future also included establishing a unifying image of sustainable agriculture, identifying key issues and participants, expanding the coalition of people who will

work on future agriculture policy, and organizing and orchestrating ahead of time.

The policy opportunities and challenges ahead were explored by a panel moderated by Kate Clancy of Syracuse University: Roger Blobaum of Blobaum and Associates; Chuck Hassebrook of the Center for Rural Affairs; Maureen Hinkle of the National Audubon Society; Jim Jontz, former Indiana Congressman; Fred Kirschenmann, farm leader from North Dakota; and Bill Lacy of Pennsylvania State University. They stressed the need for better coalitions, skilled labor, and sustainable communities to reach sustainable agriculture's full potential.

Bob Bergland, former Agriculture Secretary and Executive Vice President and General Manager of the National Rural Electric Cooperative Association, made the closing remarks at the conference, which he had hosted at the NRECA building in Washington, D.C.

IAA Conference Proceedings Now Available

The proceedings of the 1992 IAA conference, *Alternative Farming Systems and Rural Communities—Exploring the Connections*, are now available for $6. Included are papers based on the presentations of 15 speakers and five work groups which explored strategies to restore or create healthy connections between agriculture and rural communities. The proceedings are available from the Henry A. Wallace Institute for Alternative Agriculture, 9200 Edmonston Road, #117, Greenbelt, MD 20770; (301)441-8777.

Farm Groups Urge Clinton to Increase SARE Funding

Several farm organizations, including the Wallace Institute, have written to President Clinton, urging him to include the SARE program and the Sustainable Agriculture Technology Development and Transfer Program (SATDTP) among the increased research and technology investments presented in the FY'94 budget proposal.

"It is our sincere hope that over the next two or three fiscal years these two programs will reach their fully authorized levels of $40 million and $20 million, respectively," the groups wrote. The SARE program, they said, "plays a unique and important role in the overall federal-state research arena;" the SATDTP would help train agricultural agents, and "improve outreach and technology transfer to the farm community."

South Dakota State University Economist is Visiting Scholar

Thomas L. Dobbs, a professor of agricultural economics at South Dakota State University, is spending time at the Wallace Institute this spring studying farm and environmental policies and programs that could foster the sustainability of agriculture. His project, which makes a major contribution to the Institute's new alternative agriculture policy studies program, expands upon his ongoing research on implementation and impacts of federal programs in his region.

Dobbs, who earned a Ph.D. degree from the University of Maryland, brings to his assignment several years of pioneering research on the economics and policy implications of sustainable farming systems in the Corn Belt-Great Plains. He served for three years on the North Central Administrative Council which directs the USDA's SARE program in that region.

OPINION cont'd from p. 4

tween family farmers and animal protectionists. Family farmers can make a convincing case that their farming systems usually offer animal protection benefits that the industrial systems cannot.

Several systems that respect animal protection have been championed by the sustainable agriculture movement. Hog farmers in Iowa are finding outdoor farrowing on pasture and other low-capital production systems profitable and enjoyable—for them and their hogs. University of Minnesota researchers have confirmed this, finding low-input hog production as productive as confinement, while requiring less capital and work for the farmers, *and* improving the hogs' welfare.

Dairy farmers in Wisconsin find that intensive rotational grazing benefits the land, their profits, and their cows' comfort and productivity. A University of Wisconsin meat scientist found that compared with formula-fed veal, grain-fed veal was cheaper to raise, as palatable, and as productive. Most important, the veal calves did not require the confinement crates that are vilified by animal protectionists.

Real animal protection at the family farm gate. Clearly, there are workable, profitable alternatives to animal factories that will benefit farmers, their customers, and their animals. Farmers need to adopt and promote these systems to demonstrate how they benefit animal welfare—and their own profits. Farmers also need to direct animal protectionists' sweeping criticisms to the corner where their critical brooms should be aimed—the animal factories.

For their part, animal protectionists need to differentiate between the positive animal welfare benefits possible (but not always present) on small and medium-sized family-operated farms, and the absence of those benefits in animal factories. There is precedent for collaborating with farmers on this issue. The Humane Society brought in livestock farmers to help it develop its "recommended humane principles" for livestock production. The Animal Welfare Institute worked with southern Minnesota hog farmers to develop a humanely raised pork product for direct marketing to consumers.

This is the kind of alliance that farmers must make with animal protectionists, environmentalists and others if they, not food conglomerate stockholders, are to be beneficiaries of livestock agriculture.

BOOK REVIEW

Crops and Man. 2nd ed. 1992. By Jack R. Harlan. American Society of Agronomy, 677 S. Segoe Road, Madison, WI 53711. 284 pp. $34 hardcover.

Starting with Charles Darwin and Alphonse de Candolle in the nineteenth century, our knowledge of the origins of agriculture and the evolution of domesticated plants has grown rapidly. Jack Harlan has been influential in this area both as a researcher and as a writer, his contributions in the latter role including numerous essays and the first edition of *Crops and Man* (1975). His strong knowledge of agricultural botany, genetics, systematics, history, and archeology, among other fields, has enabled him to provide a unique and masterful synthesis that covers not only the biology of crop plant evolution, but also the cultural interactions between crops and man. He emphasizes that crops have "domesticated" man by their major influence on human societies during the past ten thousand years.

This is a fascinating area for training our young biologists, agronomists, social scientists and philosophers alike, and Harlan's book would be the suitable text. It covers the geography and history of agriculture (where and when agriculture began), cultural and ecological factors (such as why man changed from hunter-gatherer to farmer), the botanical and genetic changes undergone by wild and weedy ancestors of crop plants, and the processes of evolution (selection, migration, hybridization). The final chapters deal with four regions (the Near East, Africa, the Far East and the Americas), covering their archeology and traditional agriculture, and the highlights of some crops that originated in each.

The second edition is longer (although two chapters have been deleted). As the author notes in the preface, "the plants have not changed that much. We do know more about maize, sesame, pigeon pea, bottle gourds, coconut and sweet potato." The epilogue (Chapter 12) has been totally revised. In his call for imitating natural ecosystems for achieving stability and sustainability in agriculture, Harlan concludes that "technology is not the only answer" (p. 242). AJAA readers should find much of value in his ecological and historical reviews of crop origins.

Harlan's treatment of agricultural origins differs from the way that many biology textbooks introduce the subject, which is to give a map showing Vavilovian centers of origin along with the comment that our earliest crops (maize, wheat, barley, pea, yams, rice) are some eight to ten thousand years old. Evidence for dates has been fragmentary, but the evidence for closest ancestors (wild or weedy species) involving cytogenetic and taxonomic studies is voluminous, even if not always conclusive. The study of specific evolutionary processes often has remained marginal, but crop evolution research has had a dramatic impact on collection, evaluation and conservation of genetic resources. Harlan has contributed to all these developments. His critical and authoritative work on several crops, including wheat, maize, sesame, and numerous forage plants, has led him to conclude that "no modern study of diversity has confirmed the intuitive geographic patterns described by Vavilov. . . . With respect to origins of agriculture, it is, perhaps, time to abandon the concept of centers of origin altogether" (pp. 51-53). In his view, "early agriculture could have evolved in a variety of settings, but the greatest opportunities would be in regions with long dry seasons" (p. 60). Harlan proposed three centers, designating the other centers with large, diffuse regions as noncenters. Based on his original collaborative work with the equally renowned crop evolutionist J.M.J. DeWet, he states that "agriculture in Africa is basically noncentric. . . When all this began is still a matter of conjecture" (p. 184). He reviews in some detail, for example, the décrue agriculture of the Nile and Niger River regions, where floods occur regularly, so that ingenious water management and cropping systems are required. These can offer lessons for sustainable farming today. Also noteworthy is the idea that livestock herding and pottery developed here long before plant agriculture.

Harlan believes that people may have invented agriculture not out of necessity, but for convenience, fun, or various ethno-religious motives: "Agriculture is not due to an idea, a discovery, an invention, a revelation, nor even a goddess" (p. 43); "Domestication is not as difficult as one thinks" (p. 130); "Man knows what he needs to know or learns what he must or else he dies" (p. 22) (we may call this the 'Harlan rule' of inventing agriculture). Agricultural economies developed not so much for food supply but for help in building great civilizations, with their splendor, wealth, power, and mystiques.

In reading Harlan's definitions, lists of plants, and their botanical descriptions (Chapters 3 and 4), one must accept the idea that crops and weeds have coevolved in close associations. This creates many taxonomic problems but also presents useful opportunities to study plants' evolutionary dynamics. Moreover, not all weeds are undesirable; many are useful as forage crops, sources of germ plasm, and so forth. Harlan provides a detailed discussion of many ecological and agricultural characteristics of weeds. Harlan and DeWet had provided widely used definitions of gene pool categories that are practical, simpler, and less formal analogues of species, races and populations. Harlan's own experience with numerous crop genera naturally led him to be flexible; he recommends that we "use experience, case by case." Chapters 6 and 7 further explore the processes of crop evolution based on human selection, migration, and opportunities for hybridization in man-made habitats, all of which lead to new patterns of variation, new cycles of hybridization-differentiation, and of course, many local varieties selected by indigenous farmers. Harlan offers many intellectual gems, such as the following from the chapter on the Americas (Chapter 11): "The world is a more attractive and colorful place because of the efforts of American Indian gardeners" (p. 232); "Aztec medicine was at least as good, and probably better, than European medicine at the time of contact" (p. 234); "Our arrogance and prejudice may have cost us dearly in wasted oppor-

tunities to learn more about Indian medical botany and zoology" (p. 234); "[Europeans] spent 400 years trying to breed the ridges off tomato when there were smooth types in Mexico all the time" (p. 226).

In the section entitled "American Indians as Biochemists," he discusses Indian plant domesticators' early knowledge. Introduction of American crops to Africa is called seeds of change (also the title of a recent book published by the Smithsonian, reflecting on Christopher Columbus' 400-year legacy). Pre-Columbian contacts among people of different continents is still a mystery, but several crop plants (e.g., yam, cotton, coconut, and sweet potato) provide interesting speculations. In general, many human societies appear to have remained isolated, developing their crops independently, until the recent historical dispersions of civilizations and empires.

Several interesting findings emerge from the chapters on the history and ethnobotany of various geographic regions. Japan achieved an advanced social development even with a hunter-gatherer economy. Chinese agriculture remained introverted until 3000 BC, or even later. Agriculture in Egypt led to an early age of prosperity, but then declined. India is at the crossroads of many sources of introduced crops, which has resulted in an impressive agricultural diversity.

Learning about individual crops provides further lessons in the ecogeography of agriculture and resource economics. Harlan has written a forceful synthesis of several fields related to crop evolution in a new epilogue entitled "Who's in Charge Here?" (Chapter 12). He does not go into details about alternative agriculture, new agronomic or plant breeding goals, or new directions for agricultural education. However, he reminds us about current crises, discussing them in the context of past experiences of human societies, and gives adequate background in the biology of agricultural plants.

Reading many of Harlan's conclusions without sufficient commentaries tempts one to challenge him. However, he has carefully studied and evaluated the issues. Still, his opinions on several matters might be a bit too strong. For example, he thinks that sampling of genetic variation for gene banks should refer only to the genes and the interacting, coadapted sets of genes or traits characteristic of land races. He also believes that *in situ* conservation is not useful, because traditional agriculture will survive only in marginal lands. But even here, he seems to have developed reasonable and flexible views.

Harlan's writing style is lucid, technically sound, and interesting. However, he does not always cite the bibliographic sources or the other reasons behind his conclusions or philosophical summaries. Therefore, in teaching with this book, I often have found it necessary to verify his statements and to give students additional readings. The book has a good bibliography, but the teacher will have to be interactive and insightful in finding supplementary materials. It does not have the usual pictorial, colorful style of many textbooks, with their ready-made study questions, selected reading lists, or boxed definition materials. Students will need a teacher's help in finding definitions, summary ideas, and good examples of research work. Besides classroom use, I recommend it for many professionals and for people in the popular media who are getting interested in the new agricultural revolution.

Subodh Jain, Professor, Department of Agronomy and Range Science, University of California, Davis.

RESOURCES

Sustaining Land, People, Animals and Communities—The Case for Livestock in a Sustainable Agriculture, published by the Midwest Sustainable Agriculture Working Group, is available for $5 from the Wisconsin Rural Development Center, 1406 Bus. Hwy. 18-151 E., Mt. Horeb, WI 53572; (608)437-5971.

A Sustainable Agriculture Resource Guide for Oregon and Washington, a 220-page book, is $9 (book #EM 8531) from Publications Orders, Agricultural Communications, Oregon State University, Administrative Services A422, Corvallis, OR 97331-2119.

Common Harvest: An Alternative Food and Agriculture Resource Directory is available for $9 plus $1.50 shipping/handling from Food Action Network, Inc., 5324 Park Avenue, Minneapolis, MN 55417-1720; (612)822-7607.

Creating a Sustainable Food System: Pioneers Tell Their Story is available for $10 from the Minnesota Food Association, 2395 University Avenue, Room 309, St. Paul, MN 55114.

Soil Fertility in Sustainable Low-Input Farming, a 26-page report, is $5 from Michael Fields Agricultural Institute, W2493 County Road ES, East Troy, WI 53120; (414)642-3303.

COMPOST Science & Utilization is a new quarterly, peer-reviewed journal published by The JG Press, publishers of *BioCycle*. A one-year charter subscription is $99 from COMPOST Science & Utilization, 419 State Avenue, Emmaus, PA 18049; (215)967-4135.

Sustainable Agriculture Directory of Expertise—1993, a 300-page book produced by the Sustainable Agriculture Network, is available for $14.95 from Sustainable Agriculture Publications, Hills Building, Room 12, University of Vermont, Burlington, VT 05405.

A 53-slide set, featuring sustainable agriculture research and education projects, is available for $30 from Leopold Center for Sustainable Agriculture, 126 Soil Tilth Building, Iowa State University, Ames, IA 50011-3120.

Organic Soil Amendments and Fertilizers, 40 pages, is $5 from ANR Publications, Dept. NR, Publication #21505, University of California, 6701 San Pablo Avenue, Oakland, CA 94608-1239; (510) 642-2431.

Guide for authors

The American Journal of Alternative Agriculture (AJAA) publishes original research on biological, physical, or social science aspects of alternative agriculture. We particularly welcome multi-disciplinary studies, but papers from a specific discipline also are invited. However, since AJAA readership is much broader than for a single-discipline journal, highly specialized terminology should be explained or avoided. The significance of a statement, or the reasoning behind a conclusion, may have to be spelled out more than in a more specialized journal. See Vol. 5, No. 1, pp 2 & 3, for an explanation of the various categories of articles.

Units

Research papers should use the International (SI, or metric) system throughout. Occasional use of common unit equivalents in parentheses is permitted, mainly for relatively exotic SI units.

Title page

The title page should give the following information (all flush left): 1) title of the paper; 2) names of authors; 3) affiliation and office address of authors, and 4) acknowledgements, if any. See examples in this issue of AJAA.

Abstract

The abstract should be 200 to 400 words suitable for readers from a broad range of disciplines. It should avoid highly-specialized terminology that might be appropriate for a single discipline journal. Take particular care that the significance of the work is made clear, even to readers from a different field.

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Provide subject matter key words suitable for use in scientific indexing.

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References should be listed in alphabetical order by author's name, and by year for a particular author (with letters after the year if needed). If a sole author is also the lead author of papers with multiple authors, use the following order: single author (by year); two authors (alphabetically by second author's name); three or more authors (by year). Repeat the author's name for each reference. Use initials only for first and middle names. Give the names of all authors in the reference; never use "et al."

Use full names of journals, institutions, conferences, etc., except for extremely familiar abbreviations like "Dept." Remember that an abbreviation familiar to you may not be familiar to readers outside your field. If in doubt, write it out.

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The entire manuscript, including abstract and references, should be typed on one side of standard-size paper, double spaced, with margins of at least one inch all around. Starting with the title page, label all pages in the upper righthand corner with the lead author's last name and the page number. Do not use hyphens unless the hyphen is part of the word.

Follow the section headings style used in this AJAA issue. All headings are flush left, with no underlining or italics.

Tables should fit on one page, be numbered consecutively with Arabic numerals, and be on a separate sheet. Leave extra space to separate columns. Every figure and table should be mentioned at least once in the text.

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How you can help support the scientific and educational needs of a sustainable agricultural system

A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

Low-input alternative farming methods address these economic and environmental challenges. Alternative production systems point the way toward more profits, more individual choice, and long-term sustainability for our food system. More must be done to develop effective ways to make sure research, education, and information sources are readily available to farmers who want to adopt these techniques.

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